Charting the Course

U.S. Space Enterprise and Space Industrial Competitiveness

Report

of the

Commercial

Programs

Advisory

Committee,

A

Subcommittee

of the

NASA

Advisory

Council,

July

1989

Foreword

America's investment in space *has already returned rich rewards in national pride, prestige in world affairs, and technology applied to needs in fields such as communications, automation, medicine, and agriculture.*

Apart from satellite communications, the focus of our space activities has so far been on exploration and technological achievements. Today, as we move closer to launching Space Station Freedom and begin to launch the Great Observatories, we also renew our efforts to help space technology take root in our free-enterprise economy.

I have watched the Commercial Programs Advisory Committee in action over the last year. Our Nation is truly fortunate to have had such distinguished leaders serve on the Committee. The partnership, leadership, and nurturing roles of the Government are important to these efforts. If we can heed the Committee's advice, we will surely reap benefits for many years to come.

John L. McLucas

John L. McLucas
Chairman
NASA Advisory Council

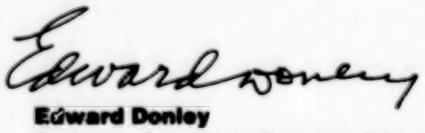
Preface

America today is faced with competitive challenges *from all points on the globe. Space is one more arena in which many of our global neighbors have challenged U.S. preeminence and have become highly capable spacefaring nations, recognizing the potential for strategic advantage and economic development.*

The 1988 Presidential Directive on National Space Policy states that a fundamental objective guiding U.S. space activities is space leadership. One of the goals was the encouragement of private-sector investment in space and related activities. President Bush, in reestablishing the National Space Council in early 1989, clearly indicated the importance he places on the commercial development of space. The Congress, in amending the Space Act, has charged NASA with seeking and encouraging — to the maximum extent possible — the fullest commercial use of space.

The Commercial Programs Advisory Committee was established in 1988 as a standing subcommittee of the NASA Advisory Council. Its purpose is to review policies and programs, and to enable and promote greater investment and participation by the U.S. private sector in America's space program. This report offers the insights of the Committee following its first year of work. It is our hope that these concepts will prove of value as new national leadership and the newly reconstituted National Space Council consider the question of American competitiveness in the world space market.

We need to build a partnership by which our country can boost new space business into the marketplace and attract thoughtful investment. Promoting space enterprise and enhancing space industrial competitiveness are challenges calling for leadership, commitment, and investment. We should not let this opportunity pass America by.



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Peter W. Wood
Consultant
Commercial Programs Advisory Committee
NASA

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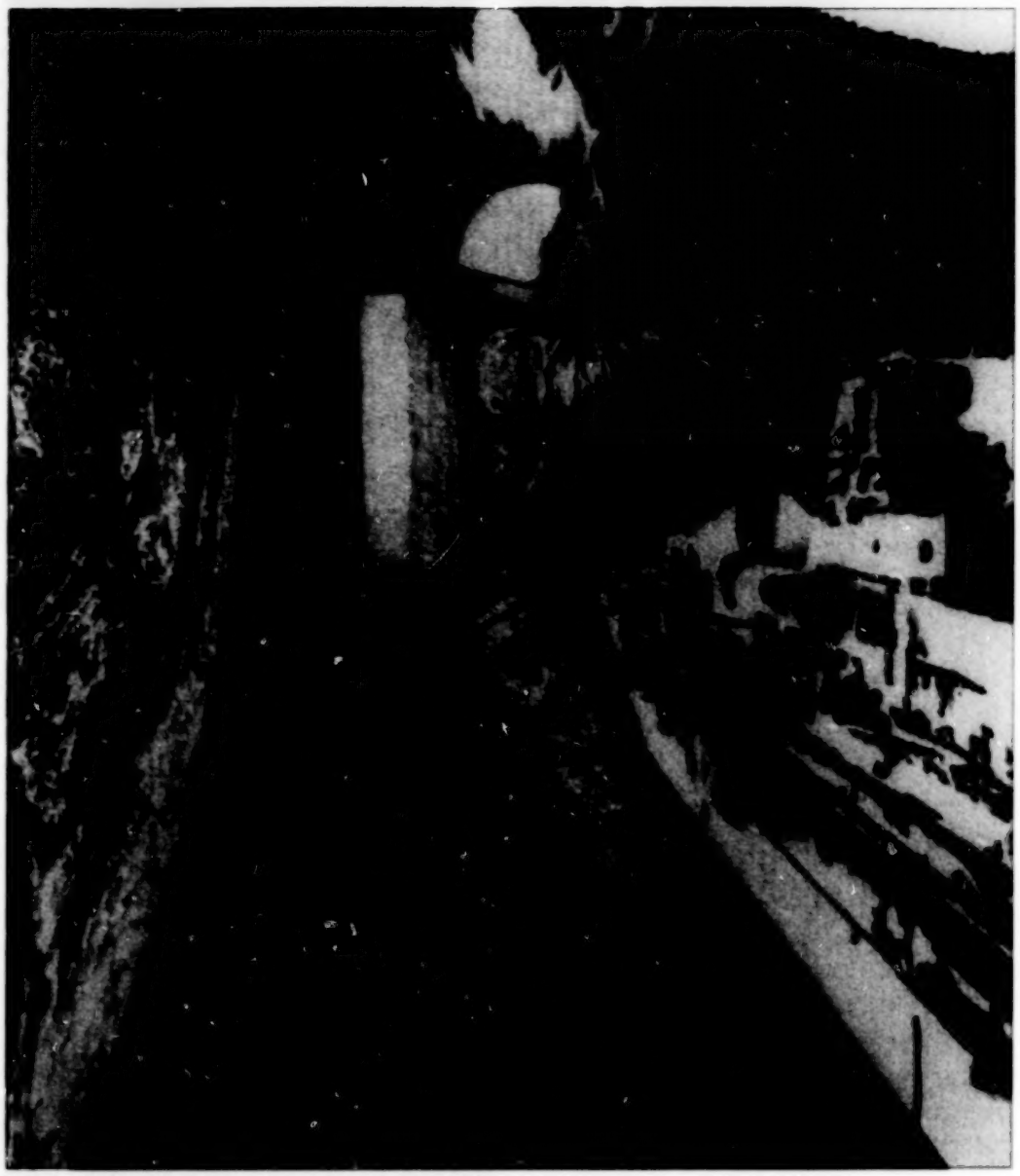


Detail of *At Work in Space*, pencil drawing by Chris Calle

America's technological leadership in space has been a symbol of national prestige, drive, and intellectual vitality, and a key to international influence for most of the space era. The earliest U.S. space endeavors to be developed commercially — communications satellites — have led to the creation of worldwide telephone and television services that today we take for granted. And there are other examples — computer technology, control systems, space launch systems — where Government-sponsored space research and development has spawned promising commercial industries.

U.S. scientific satellites and planetary probes have brought a new understanding of the solar system with close-up glimpses of neighboring worlds. From the vantage point

of space, images of coastlines, forests, and clouds have unmasked the fragility of our own planet's environment. By removing gravity from the equation, experiments aboard the Space Shuttle have revealed new possibilities for breakthroughs in many domains of science, from material properties and combustion to biotechnology and human physiology.

Looking ahead, the promise of continuous, long-term access to space will open another new era for U.S. space technology. In July 1989, on the twentieth anniversary of the first landing on the Moon, President Bush announced two new objectives — establishing a lunar base and exploring Mars in the next century. Meanwhile, through the planned Space Station *Freedom* and orbital platforms, space will become a new laboratory, factory, and waystation to the planets — and a new basis for space enterprise.

A New Economic Frontier

As U.S. Government, industry, and academic leaders answered the challenge of space exploration in the last three decades, new technology emerged and brought with it a substantial return on the space investment. A survey of a limited sample of companies capitalizing on spinoffs from National Aeronautics and Space Administration (NASA) technology identified benefits of more than $20 billion in the 1980's.[1] Advances in computers, microelectronics, materials, electrical power, inertial systems, computational fluid dynamics, and thermal control have improved the lives of many Americans and have expanded the U.S. industrial base. Today, space technology is at a turning point. So far, one truly viable space industry has emerged from space exploration: satellite communications. This has become a multibillion-dollar industry in the United States and is a growing business in several foreign countries.

Now, new commercial opportunities for businesses and the potential for national economic growth are emerging in several markets, notably launch services and space facilities. Business appears poised to take the lead in developing other new space-based enterprises. The most promising markets include the following:

- **Satellite applications** — not just for communications, but for Earth observation, meteorology, resource development, navigation, geopositioning, and asset tracking;
- **Launch capabilities for transporting satellites and structures into space** — vehicles and their supporting ground facilities, maintenance, and logistics resources;
- **Facilities for working in space** — life sciences and microgravity research equipment, material-processing hardware, data support, automated sample-return systems, logistics, and crew support; and
- **Research and development opportunities** — potential advances in health care, semiconductors, substrate materials for electronics, thin-film technology, polymers, glasses, plastics, high-performance alloys, agriculture and food technology, and energy systems.

Successful development of space enterprise in these and other new space markets not only will help ensure continued U.S. leadership in space, but will also contribute to economic growth and industrial competitiveness, improve the U.S. high-technology trade balance, and enhance national security.

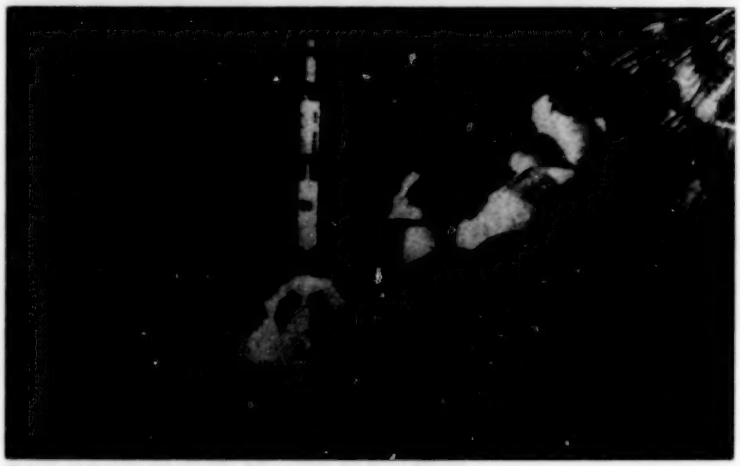
The Global Space Business

Thirty years ago, the sole challenger to U.S. space leadership was the Soviet Union. But with the reconstruction of the industrial base in Europe and Japan, other nations have developed significant capabilities in space technology. Today, the European Space Agency (ESA), with 13 member nations, has an ambitious space program. The French Ariane launch vehicles and SPOT Earth-observation system have quickly gained strong positions in the transportation and remote-sensing markets. Other players include West Germany, Italy, the United Kingdom, Canada, the Soviet Union, and the People's Republic of China, with Japan and others soon to follow. Hence, America is challenged by formidable competition in all sectors of the commercial space market.

U.S. space industries face competing firms that are supported, coordinated, or to some extent owned by a foreign government. Arianespace, the launch vehicle company owned by Centre National d' Etudes Spatiales (CNES), the French Government's aerospace research establishment, European industry, and European banks, has captured more than 60 percent of the free world's launch market in only nine years. Aside from profit, the rationale for such heavy government involvement includes national objectives such as creation of strategic advantage, enhanced technology development, employment, and balance of trade. As a result, the U.S. space industry can no longer count on building an unchallenged market share or on being first to market.

Space and U.S. Competitiveness

Used to a dominant position in post-World War II global industrial output, the United States has lost near monopolies in consumer electronics, semiconductors, and machine tools. By 1986, the United States had lost a high-technology balance of trade that had exceeded $25 billion in 1980. Europe and Japan are challenging the U.S. lead in pharmaceuticals and computer software. American industrial competitiveness has become a major national issue.[2]



Detail of Apollo 11 launch, lithograph by John Meigs

Space commerce can offer more than an opportunity for U.S. private enterprise; it ultimately can represent a contribution to American competitiveness in the global market. As the NASA Advisory Council Task Force on International Relations in Space has pointed out, "a single $100-million launch contract is equivalent in economic terms to the import of 10,000 Toyotas."[3] Although the foreign market for U.S. launch services is limited, and space is just one of the future contributors to competitiveness, it is a field in which U.S. technology has earned great world respect. At the same time, major space projects offer increased opportunity for international cooperation at the industry level. Such teaming arrangements will often be in the national interest.

What Is Needed?

U.S. space enterprise needs a supportive environment in which to overcome the barriers and risks of developing the new space business frontier. American industry must be concerned not only with the strategic moves of aggressive competitors abroad, but also with a host of challenges at home — such as national policy, Government regulation, resources, access to space, technology development, capital formation, and markets. The United States must decide whether to pursue leadership in the global space market. Clear goals, strong leadership, and a close partnership between the Government and industry will be needed to take advantage of emerging space opportunities.

Although the White House, NASA, and other governmental agencies such as the Departments of Commerce, Transportation, and Defense have been supportive of commercial space development, Government efforts have lacked common goals, central direction, and leadership. In the hope that a new Government-industry partnership can be forged to develop a strong commercial space sector and improved U.S. competitiveness, the Commercial Programs Advisory Committee has formulated a number of recommendations.

Key Recommendations

In the belief that space represents an important opportunity for the Nation's economy, welfare, and prestige; that an effective approach to space enterprise is urgent; and that in our current stage of private-sector involvement, the process needs continued nurturing by the Government, the Committee offers the following key recommendations,

Detail of *Day of Launch, STS-2*, mixed media drawing by Bill Robles

supported by additional recommendations in four functional areas.

What Executive Branch Leaders Should Do

The President and top executive branch leaders should vigorously endorse the development of U.S. space enterprise and space industrial competitiveness as national goals. In July 1989, President Bush reaffirmed the goal of establishing the United States as the preeminent spacefaring nation. He had previously emphasized space commerce in his congressional budget address and in the Executive order reestablishing the National Space Council. Continued White House support and public endorsements from the NASA Administrator and the Secretaries of Defense, Commerce, and Transportation will convey the significance and priority of these goals to the public-sector team — the relevant Government departments and agencies working together as partners — and to the Nation.

Centralize executive branch leadership for civil and commercial space under a single authority by assigning the NASA Administrator the additional role of Director of Civil Space. The President should direct the NASA Administrator, as

Director of Civil Space, to coordinate the civil and commercial space activities of all departments and agencies. (The NASA Administrator is a member of the National Space Council.) The Director would draw on NASA space expertise, facilities, and technology to advance U.S. space enterprise and industrial competitiveness, and would work closely with the heads of other involved agencies to ensure consistent policy implementation.

Form a permanent industry advisory committee to advise the National Space Council and the Director of Civil Space (if one is appointed) on U.S. space enterprise and space industrial competitiveness. As an element of the recently established Vice President's Space Policy Advisory Board, this industry advisory committee would evaluate, monitor, and offer counsel on national strategies, plans, and actions on space enterprise and competitiveness. Committee members would be drawn from the top ranks of U.S. industry, as well as from the financial and academic communities.

Establish a national program to improve U.S. space industrial competitiveness. The Director of Civil Space, assisted by the industry advisory committee, should establish specific goals for U.S. space enterprise and lay out a national program for ensuring U.S. leadership and competitiveness in commercial space. A well-conceived program would assist in unifying actions and stabilizing national policy.

What Government Agencies Should Do

Provide vigorous support to U.S. space enterprise. For U.S. space companies to compete successfully, vigorous Government support is urgently needed. Space enterprise in the United States will expand with the civil and defense space sectors of the Government acting as sponsors and customers. Broader support from NASA is especially needed in new market sectors. NASA funds for commercial space development should be substantially increased to accomplish four objectives:

- Ensure routine space transportation at modest or no cost for qualified new enterprise and research payloads;
- Augment and focus the Centers for the Commercial Development of Space;
- Provide space facilities, infrastructure, equipment, and expertise; and
- Continue advanced research and technology supporting the commercial development of space.

The Departments of Defense, Commerce, and Transportation should expand their programs to encourage space enterprise and competitiveness, and they should work with NASA as partners committed to developing a robust and competitive space industry.

Seek ways to assist new space enterprises in attracting capital. Government agencies can share the risk or reduce the costs of space research, business startup, and transportation for emerging space enterprises in many ways. Examples include providing free launches for certain R&D experiments, exchanging scientists with industry, and acting rapidly on private-sector requests. In addition, the Government could use creative financing mechanisms such as guaranteeing part of the principal on private-sector zero-coupon bonds. (Where an enterprise stands to profit, it should bear the risk for some significant portion of the investment.) These measures will make space enterprise more attractive to capital markets.

Be prepared to serve as an anchor tenant or key customer of new private-sector space products, services, and infrastructure. The principal obstacle to new space ventures is the uncertain market demand. The Government can make an important contribution by using its purchasing power to promote such commercial ventures. Wherever possible, Government needs should be met through the purchase or lease of commercially offered products, services, and infrastructure. Furthermore, the Government should not influence the design of infrastructure in a way that would prevent later use by the private sector.

What Congress Should Do

Congressional committees have played an important role in promoting the development of space enterprise. In addition to supporting and encouraging the initiatives taken by industry, the executive branch, and other Government agencies, Congress alone can act on two recommendations.

Authorize multiyear commitments to purchase or lease space goods and services. Long-term customer commitments are essential to persuading private-sector investment in space-enterprise capital formation and technology development. As a customer, the Government should be able to commit to lease or purchase over a 5- to 10-year period.

Pass legislation to provide substantial incentives to industry for investing in space technology. Space technology is a strategic tool for the United States. Establishing and holding a competitive position will require years of private-sector investment, despite considerable risk and market uncertainty. Recognizing the strategic and economic benefits of past efforts to develop shipping, railroads, and airlines, the United States should offer R&D, capital-gains, and other investment incentives to develop a commercial space sector that is a strong competitive force in the world market.

Other Recommendations

In addition to these key recommendations, the Commercial Programs Advisory Committee offers a number of recommendations in four functional areas:

- **Policy stability and consistency** — measures dealing with developing a responsive policy formulation, implementation, and followup process, setting industry objectives for space enterprise, and designating key contacts at Government agencies and at NASA centers.

Detail of *Connecting Gloves*, drawing by Henry Casselli

- **International competition and cooperation** — measures addressing commitment to space competitiveness,

protection of intellectual property, rational unified approaches to administering technology-transfer policy, equal market access, and strategic goal setting. Other recommendations provide for Federal Government assistance in assessing the level of foreign government intervention in commercial space development, the conduct of international trade studies to assist in industry-Government goal setting, and Government assistance to space startup firms to bolster competition with foreign entities.

Although national competitiveness urgently requires enhancement, and space enterprise will ultimately make a contribution, competitiveness does not preclude cooperation. International cooperation in space is clearly in the national interest, especially in major programs for the common good. There are many situations in which U.S. space enterprise can benefit from foreign technology and the participation of foreign space interests. U.S. industry is capable of leading cooperative space ventures without threat to its competitive position.

- **Finance and private industry incentives** — measures the Government can take to ease startup burdens and foster the assembling of capital needed for new space ventures, including expanding NASA's Centers for the Commercial Development of Space and enhancing the centers' industry focus and broadening Government procurement guidelines to support the use of commercial products and services. Included are recommendations for multitiered space transportation pricing to encourage space enterprises such as infrastructure initiatives and expanded use of the Small Business Innovation Research program.
- **Political and public opinion process** — measures to expand knowledge of the potential of space enterprise throughout the Government, industry, finance, science, and academic communities. Increased availability and quality of materials for communications, improved terminology, and media support from participating universities and industry in reaching a broad audience are features of the recommendations.

Conclusion

The nature of the space race has changed. In the past, America's leadership was built on excellence in space exploration and technological advances. In the 1960's, the key question in space was which nation would be the first to land on the Moon. America won that race.

In the future, success in space will be determined by a wider set of activities, including commercial space activities in a competitive global marketplace. An increasingly important goal for the 1990's and beyond is to complete the evaluation of the commercial promise of space and move rapidly to exploit that promise. America cannot afford to lose this race.

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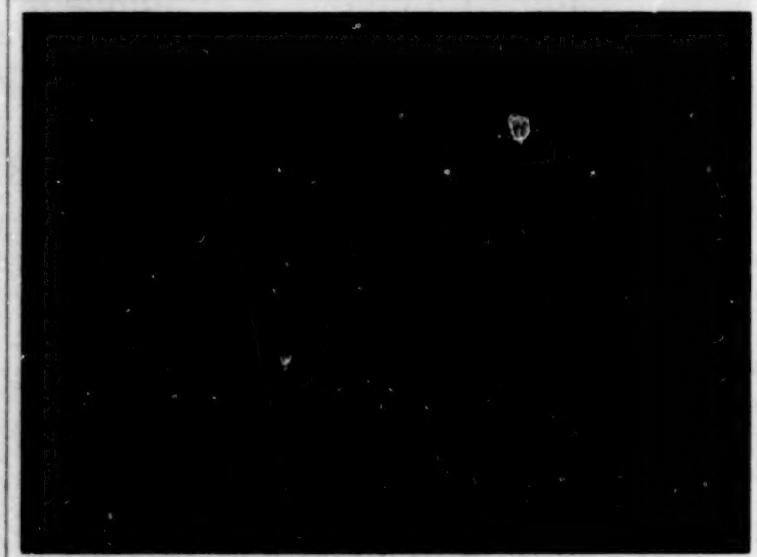
Detail of *51-G Lift-off*, watercolor by Philip Jamison

Spacefaring has become a global enterprise. Even third-world nations have launched satellites to meet their special needs. And in recent years, a growing number of nations have begun to exploit the commercial potential of space. In this report, the Commercial Programs Advisory Committee examines the challenge and opportunity of building a new sector of the U.S. economy on the basis of space technology in the face of world competition. In particular, the report focuses on the environment in which this commercial space sector is developing, the issues and obstacles that must be addressed, approaches and goal setting, and the roles of Government and industry in bringing about a successful entry into the commercial development of space — both as an element of enterprise and as an ultimately significant factor in national

competitiveness and prestige. This chapter briefly examines the international and national environment for commercial space. Chapter III focuses on issues to be addressed in developing commercial space and suggests goals in each of six major issue areas. Chapter IV outlines roles for the Government and industry. Chapter V offers the Committee's findings and its recommendations.



Detail of *Spacelab 1*, oil painting by Charles Schmidt

President Bush, in his remarks marking the twentieth anniversary of the first landing on the Moon, said:

> The U.S. is the richest nation on earth — with the most powerful economy in the world. And our goal is nothing less than to establish the United States as the preeminent spacefaring nation.

Such preeminence in space should certainly include a prominent role in the commercial use of space technology. So the United States has embarked on a new era in space development, one in which industry will play a central role. The goal must be to establish the United States as a strong competitor in international commerce.

From NASA's inception, it has been goal- or mission-oriented in fulfilling its original charter to expand scientific knowledge of the universe. In its early days, NASA was motivated by the challenge of a major competitor nation (the USSR), pride in its ability to lead space exploration, and a President who was committed to positioning the U.S. as the preeminent leader in space. NASA rose to that challenge, and America developed unsurpassed expertise in space.

The climate has changed since those early days. Today, there are new challenges: budget deficits, international trade deficits, mounting concerns with the global environment, vigorous foreign space activity, and the increasing cost and complexity of space missions. In 1984, NASA's charter was revised to charge the agency with "seeking and encouraging . . . the fullest commercial use of space." NASA's expertise and resources are needed now to support emerging space enterprise and to help the United States be competitive in the international space industry for the decades ahead. But, as President Bush has recognized, space enterprise is a national challenge. It requires leadership at the highest level, substantial industry initiative, and coordinated support by many departments and agencies, and by Congress.

Global Space Competition

Foreign governments are using their space programs to develop competitive advantages. A study conducted by the NASA Advisory Council's Task Force on International Relations in Space found that the space capabilities of the Soviet Union and Europe are growing rapidly, with China and now Japan not far behind.[4]

By the last half of the 1990's, Europe and Japan will have become self-sufficient in most commercial space market sectors. All will be competing aggressively with the United States for market share and technical achievement.

While in recent years the U.S. Government has shown signs of greater commitment to stimulating and promoting U.S. industrial competitiveness in space, many foreign space agencies are promoting their industries through direct intervention in the planning and decision-making. The U.S. Government's support and promotion are too scattered and diluted to have a substantial impact on competing with these forces. The subsidization and guarantor functions carried out by these foreign governments are all but absent in the United States. A closer look at these foreign space programs illustrates the competition faced by the United States.

USSR

The Soviet Union has recently demonstrated significant advances in several key space technologies. It is aggressively seeking Western customers for its launches and partners for space science projects. Glavkosmos, the USSR's civil space organization, has initiated a new commercial marketing strategy, complete with a new organization, sales force, and brochures offering launch services, schedule reliability, pricing flexibility, and security for the customer's property.

Europe

The European Space Agency (ESA) is a consortium of 13 Western European nations, one associate member, and Canada, which has a cooperative arrangement with ESA. Organized in 1975 to conduct space projects of mutual interest to its members, ESA has placed high priority on the development of national and European industry "to improve the competitiveness of European industry in application areas." Member countries agree on projects conducted by ESA and the funding contribution for each. ESA membership does not prevent members from independently initiating space projects. In fact, some member nations specifically instruct their agencies to increase their share of foreign markets.

Commercial space consortia are an active part of the European scene. The most prominent is INTOSPACE, in which nearly 100 European companies have invested to promote and exploit industrial applications of space.

France has the largest space budget and contributes 47 percent of ESA funding. The French space agency, Centre National d'Etudes Spatiales (CNES), has had a key role in founding 14 commercially oriented corporations and maintains at least a 25 percent interest in 10 of these groups. Arianespace (an ESA initiative of which CNES owns 34 percent) markets and operates the Ariane launcher.

In only a few years, Arianespace has captured 60 percent of the commercial launch market worldwide, deriving annual revenues of about $600 million. In addition, there are strong indications that prices quoted by Ariane are governed not by cost, but by market. Until recently, the chairman of Arianespace was also the director general of CNES. SPOT Image, also founded by CNES, has become a major competitor in the worldwide remote-sensing market.

Japan

Japan's National Space Development Agency (NASDA) was established in

1969 as a "special corporate entity" charged with prime responsibility for implementing "practical applications of space developments." Although Japan's space technology is developing later than others', it is working on satellites and large launch vehicle capabilities, including the H-II, an Ariane class 4 vehicle, scheduled for first flight in 1993.

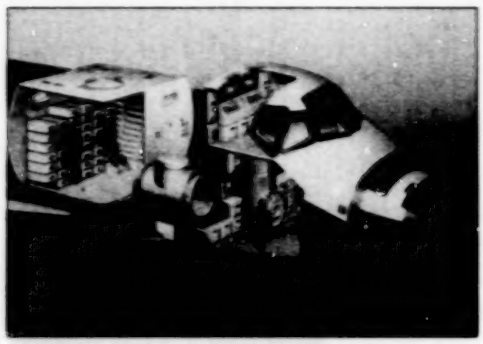
In Japan, space research is viewed as vital to maintaining competitiveness in high technology, and space capability is considered to have a long-term, large-scale commercial potential. Further, space activity is seen as a logical extension of Earth business. Space science is seen as a key technical discipline that must be mastered to ensure future economic growth.

In 1987, the Japanese Space Activities Commission's Consultative Committee on Long-Term Policy released its plan, *Toward a New Era of Space Science and Technology*, which charts a course for the rise of Japan as an autonomous space power. The plan calls for the promotion of space development as a national project requiring government leadership. Government will encourage private investment through its own investment and loans, tax breaks, provision of testing facilities for public- and private-sector use, and technology transfer to the private sector.

Japan is a partner in Space Station *Freedom* and will provide an attached laboratory module. Given its technological record and the care with which it is preparing for a future in space, Japan can be expected to play a prominent role in commercial and scientific space activities by the mid-1990's.

People's Republic of China

China's space program is expanding toward active participation in the world



SPACEHAB Module in Space Shuttle

market. Its principal activity of commercial interest is the Long March family of launch vehicles. China, which invented the rocket in the fourteenth century, developed and launched its own satellite into an elliptical orbit as early as 1970. Offering launch services since 1985 at very modest prices, China completed a successful commercial launch of several experiments on Long March II in 1987 for a French industrial customer. This vehicle can reportedly lift more than 5,000 pounds to low Earth orbit. Long March III is expected to launch satellites of 3,000 pounds to geosynchronous transfer orbit, and larger payload capacities are planned.

The Beijing Wan Yuan Industry Corporation, which manufactures the Long March launch vehicle, is part of the Ministry of Aerospace, as is the Great Wall Industry Corporation, which is the marketing and contractual company for the vehicle. China operates two launch sites, in the northwest and southwest regions of the country, and a satellite control center in Xian. Political disruption in 1989 has caused some loss of confidence in the ability of China to meet near-term launch commitments, notably to Australia's AUSSAT program.

Summary of the U.S. Space Program

The national space program comprises three separate, but interdependent, elements: national security, civil, and commercial space.

National Security Space Sector

The national security space sector accounts for approximately two-thirds of the total U.S. space budget of about $30 billion. Its primary focus is ensuring national security and supporting combat readiness. Representative programs under this sector include Navstar, a satellite-based navigation system; Milstar, a communications satellite system; the Defense Meteorological Satellite Program, intelligence and surveillance systems; and the Strategic Defense Initiative. Defense satellites are used for early warning, nuclear test detection, and intelligence gathering.

Following the explosion of the *Challenger* in 1986, the military began to rely more heavily on expendable launch vehicles for its launches, but continues to launch several payloads per year on the Shuttle. The national security sector is largely responsible for reestablishing the expendable launch vehicle industry in the United States and is now exploring development of the Advanced Launch System, planned as a low-cost, heavy-lift launcher to be operational by about 2000.

Civil Space Sector

The civil space program, led by NASA, seeks to improve our understanding of the solar system, the universe, and the Earth through study and exploration. NASA is poised to begin some of the most extensive space science research since its inception.

Over the next five years, NASA is scheduled to launch 35 new space science and applications missions, including several planetary missions and the four Great Observatories: the Hubble Space Telescope, Gamma Ray Observatory, Advanced X-Ray Astrophysical Facility, and Space Infrared Telescope Facility.

Design of Space Station *Freedom* is nearing completion, and the next few years will bring extensive hardware fabrication and testing before launch and assembly in space in the mid- to late 1990's. International partners in the Space Station include ESA, Canada, and Japan.

Vital to both Space Station *Freedom* and space science research is the Space Shuttle. Maintaining safe and timely Shuttle operations is the main challenge facing NASA today. Shuttle mission length will soon be increased to 18 days or more with the implementation of the Extended Duration Orbiter modification, thus permitting somewhat longer-term experiments. But NASA has also returned to some use of expendable launch vehicles and is planning the development of new space transportation, with emphasis on heavy-lift capabilities.

Commercial Space Sector

The commercial space sector is the domestic, private-sector organizations involved in initiating, directing, funding, developing, and marketing space products and services. This sector is still in a relatively early stage of development. Private-sector space businesses seek military, NASA, and commercial customers for the following:

- Space-based communications and information services (satellites);
- Space transportation;
- Space infrastructure (facilities, hardware, software, and systems); and
- New products and services (including materials processing in space and life sciences).

Revenue from satellite communications, the oldest and most successful segment of the commercial space program, is estimated at about $3 billion annually for satellite manufacture, launch, and support, with secondary revenues (such as from long-distance telephone service) amounting to many times this figure. Materials processing in space and life science endeavors are still relatively immature because extensive flight time for research and microgravity experiments is needed to develop new products and processes.

NASA's Role in Developing Commercial Space

The Government played a critical role in the early days of the commercial communications satellite industry, chartering the Communications Satellite Corporation (COMSAT) and giving it a protected monopoly in international communications until the mid-1980's. NASA has since established an extensive system for encouraging the early phases of commercial space ventures.[5]

Today, NASA's commercial space development efforts have reached many industries. Nearly half of the top 50 *Fortune* 500 companies are involved in commercial space research and development, although in most cases, activities are thus far limited to affiliate roles in NASA Centers for the Commercial Development of Space. NASA now carries out this effort primarily through its Office of Commercial Programs. Approaches used to encourage commercial space development include Government-industry agreements for services, the nationwide network of NASA support centers, and other special programs.

Centers for the Commercial Development of Space. NASA currently supports 16 research centers for the benefit of university, industry, and Government research and early testing of space-related products or services with commercial potential. Each center receives part of its support from several industrial affiliates, which also participate in setting research objectives.

Joint Endeavor Agreements. Nine U.S. companies with resources committed to space product or service development currently have Joint Endeavor Agreements in effect with NASA for access to Space Shuttle launch services for experiments, research, and development. Several more agreements are in negotiation.

Space Systems Development Agreements. Space Systems Development Agreements allow businesses expecting revenues on early development flights of a new product or service to defer payments for launch services. One company that has reached such an agreement with NASA is Spacehab, which has developed a commercially manufactured cylinder that fits in the Space Shuttle cargo bay to augment middeck experiment space. The European consortium INTOSPACE has agreed to rent a large block of Spacehab experiment space and lockers.

Other Launch Services. In addition to the Space Shuttle, NASA can arrange for the purchase of commercial launch services, including expendable launch vehicles and sounding rockets for private-sector research and development, and can provide infrastructure and equipment support.

Space Station. NASA's Office of Space Station is working with the Office of Commercial Programs to accommodate private-sector projects on Space Station *Freedom*.

Materials Processing in Space. Key to developing new products in space is development of a data base on microgravity research. The NASA Office of Commercial Programs is working to expand the number of flight experiment opportunities for this purpose.

Small Business Innovation Research Program. In 1988, NASA awarded 204 starting and 85 follow-on contracts for developing commercial applications of space research. With

Detail of *Space Station*, acrylic by Vincent Di Fate

$175 million spent or committed since 1983, NASA has funded 446 small businesses in 40 states, territories, and the District of Columbia. Most of these businesses are still in the research stage.

Industrial Applications Centers. The 10 Industrial Applications Centers and their affiliates are the heart of NASA's technology-transfer network. They provide information retrieval services, assistance to industry, and dissemination of NASA information useful to entrepreneurs wishing to make commercial use of space technology.

Other Entities

Other Government departments and agencies, notably the Departments of Defense, Commerce, and Transportation, have directed their attention to space commerce as well. Activities of these departments in support of space enterprise are summarized under "Government Progress in Encouraging Industry Involvement in Space" in Chapter IV.

Commercial space is emerging as a new economic sector in the United States. It is distinct from the national security and civil space sectors because the initiatives and investment needed to make it grow must originate in private industry. But, in its formative stages, the commercial space sector must depend, in part, for its business base on national security and civil space programs and needs the Government to provide a nurturing, constructive environment. U.S. space enterprise will face significant foreign competition; nevertheless, it can be expected to play a valuable role in improving the Nation's international economic competitiveness.

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Detail of *Hail the Traveler*, oil painting by Robert A. M. Stephens

The key question for the Government and industry is this: Does the United States want to be a leader in the global space market? The Commercial Programs Advisory Committee believes the answer must be yes.

Early space research and technical development suggest opportunities for economic return of significant value to the Nation will come from new commercial products and services in such strategic fields as environmental monitoring, energy, development of natural resources, health care, and information technology, as well as national security. Establishing early leadership in such industrial space markets is important to U.S. success in commercial space.

Recovery from the loss of a lead position in any economic sector has always proved difficult. There have been few historical instances of the United States holding, losing,

and then regaining market leadership. Televisions and consumer electronics are examples of lost markets never regained. Although being first to market does not ensure continued strong market share, it clearly is an advantage. U.S. industry's traditional strength has been as technology leader and first to market, rather than as a market follower.

In the past, industry's role in space has been limited primarily to that of the traditional contractor on Government projects. Commercial space ventures today represent only a small fraction of industry's total role in space. As new products and services are identified, markets will begin to develop, and the true commercial portion will grow. Application of further discoveries and the development of reliable, low-cost transportation systems will enable entirely new industries to emerge.

Government support is needed to reduce the risk of these ventures and provide incentives to encourage industry participation, particularly in the early stages of space business development. Until commercial markets develop, the Government will continue to be the largest customer for the space industry.

Like many industries in this decade, industries interested in space are faced with problems: foreign competitors capturing market share, restrictions on technology exports, the high cost of capital, and slow definition and growth of markets. Although not unique to the space industry, these problems loom larger because the markets are less defined. Government involvement in the space industry is necessarily greater than in other businesses. Because many agencies play such an important role in space industry, Government leadership and coordination are needed to ensure that joint Government-industry efforts to develop space commerce are balanced, rational, and productive.

At the national level, goals must be balanced among national security, scientific advancement, foreign affairs, economic development, and other objectives. For example, the conflict between national security considerations and the needs of the commercial market for Earth imagery threatened for a while to impede progress for the remote-sensing business. Yet economic deterioration can become a national security risk itself, a factor not to be overlooked when resolving such conflicts.

To achieve a balance of national goals, leadership must be guided by a strategic understanding of how the Government can encourage U.S. industry to further develop the space frontier and compete in the global market.

As a basis for understanding what is needed to develop space business opportunities, this chapter provides a discussion of risk management and then examines six groups of issues related to space enterprise:

- The national environment,
- The international environment,
- Access to space,
- Technology and product development,
- Markets, and
- Capital formation.

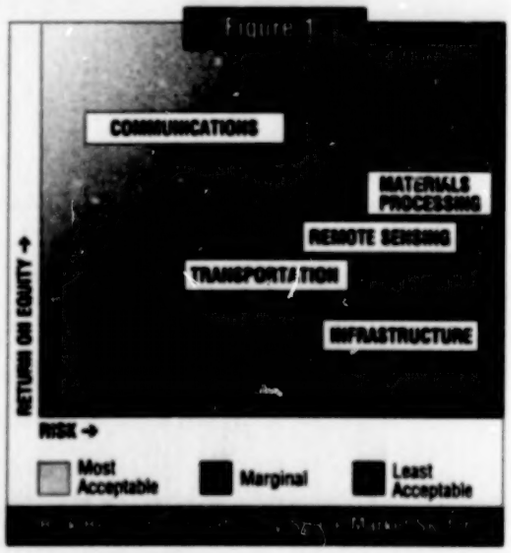
The discussion of each of the six issue groups concludes with a related goal to foster U.S. space enterprise.

Videotaped interviews with more than 60 leading space industry executives (listed in "Acknowledgments" at the end of this report), relevant studies on various actual and potential markets for space products and services, and the results of eight major reports formed the basis for the identification and examination of these issues and promising solutions.

One of the reports, *Issues in Strategic Planning for Commercial Space Growth*, published by the American Institute of Aeronautics and Astronautics in 1989, is complementary to this report in that it examines and suggests time-phased goals for elements within various commercial space market sectors. The report is based on a series of workshops in which more than 90 space specialty experts participated. Several briefings on this work were given to the Commercial Programs Advisory Committee during its deliberations.

The Entrepreneur as Risk Manager

The issues in the six groups describe obstacles to progress in developing space enterprise. These issues have a common denominator: they translate into risk for the potential space



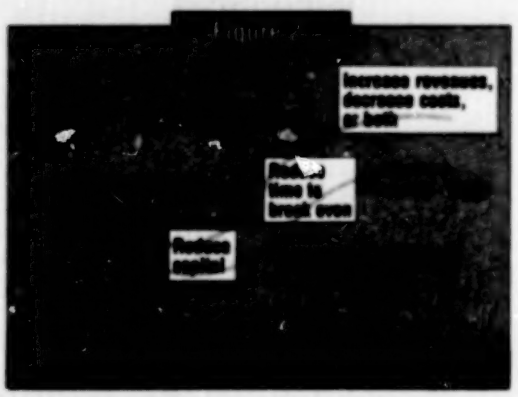
entrepreneur. *Figure 1* is a conceptual risk-return profile for various space industry sectors. Today, most sectors fall outside the acceptable region, indicating that risk is not yet compensated by potential return. To attract private-sector investment or capital, the entrepreneur seeks ways of reducing risk or increasing return, or both. Entrepreneurs must find ways to achieve for their ventures an acceptable combination of risk and potential return.

For space ventures, many aspects of this situation are likely to depend on policies, actions, and practices of the Federal Government, as well as on specific measures by which the Government can help a specific venture. Measures for reducing the various types of risk include the following:

- **Technical risk** — jointly funded R&D programs, accelerated technology transfer to industry, and Government or academic R&D programs directed toward specific private-sector needs;
- **Schedule risk** — frequent, reliable access to space, sound planning and management, timely Government actions, and accelerated R&D;
- **Market risk** — the Government as anchor tenant, or key customer, reliable products and service, timely arrival at market, sound space transportation pricing policies, cooperative agreements, access to foreign markets, and a level playing field;
- **Political risk** — stable and consistent policy implementation, and multiyear funding;
- **Cost risk** — favorable action on all other types of risk, plus stable, moderate costs for research, development, transportation, insurance, money, and operations; and
- **Contractual risk** — procurement streamlining, contract guarantees, protection for innovative ideas, and termination liability.

Methods for increasing return *(Figure 2)* are traditional, and include the following:

- **Increasing revenue** — increase price, unit sales, or the overall market size;
- **Reducing expenses** — employ cost-reduction programs, new technology to avoid or reduce recurring costs, free or low-cost use of Government facilities, and tax incentives;
- **Reducing time for return** — reduce capital needed, increase revenues or decrease cost, or both (the earliest possible break-even point is important); and
- **Reducing capital requirements** — lower the cost of capital and delay the need for outlays, joint ventures in which the Government pays for some R&D and industry funds production, and deferred payment incentives.



These factors are, of course, highly interdependent. Properly adjusted, these factors can mitigate risk and enhance return, thus increasing the probability of a venture being perceived as viable and, therefore, increasing the ease of obtaining funding. In addition, many national objectives — whether strategic, programmatic, or economic — can be attained as the private space sector grows and flourishes.

The framework for managing risk and return starts with solving issues and problems at the national and international levels. Through reduction of risk at these levels, the risks for market and technology development and for financing progressively diminish.

Strategic market positioning of the United States in the world market will require joint Government-industry interaction to focus on industrial competitiveness in space. This partnership will also serve as a catalyst for accelerating development at the level of the individual venture. Industry must work with the Government to identify barriers and recommend solutions. It is important for industry to adopt a strategic investment mentality.

Reducing risk should be considered as an appropriate joint role for the Government and industry during the early stages of each space market sector. Market stimulation, however, depends on the issues facing each phase of business development. Some measures, such as the need for new technology to avoid or reduce recurring costs, apply to all sectors throughout the business development cycle.

One interesting solution to the period of greatest risk is particularly applicable when the Government is initially the only customer. This approach leaves initial commercial operation in Government hands until the business is profitable and other customers are added, at which time it is sold to private-sector interests. This pattern was followed in the case of Western Union, which started as a Government operation, an outgrowth of the test telegraph line built by the Government in 1840 from Washington, D.C., to Baltimore. Without such help in managing risk, most space entrepreneurs will find it difficult to obtain the financing to embark on space projects.

Detail of *Mission Specialist Shannon Lucid*, drawing by Hugh Laidman

Each market sector is unique, and the appropriate financing mechanism depends on the issues or risks facing investors that evolve with the various phases of development. Accordingly, a phased approach to specific Government participation is needed, as described in Chapter IV.

National Environment

The private sector clearly has the lead role in developing commercial space products and services. Nevertheless, space commerce will remain greatly dependent on Government actions and policies, especially in the early years of space commercial development. This dependence has two fundamental causes. First, space is viewed as the province of all nations and subject to international treaties and regulations, which makes the Departments of State and Commerce, the U.S. Trade Representative, and agencies with policy, technology-transfer, or budgetary responsibilities important players. Second, the Government has pioneered the exploration and use of space and is still the primary user and regulator of space activities. For this reason, decisions to invest in space-related ventures are especially sensitive to Government policy.

The stability of Government policies over time is critical to space investment decisions because space ventures typically require long development cycles. Five- to seven-year cycles are not unusual for new space products or services; pharmaceutical products may take 10 years. If Government policy shifts after industry commits to developing a product, industry can suffer losses. Frequent changes in commercial space policy have contributed to the overall perception of space as a high-risk investment, and this perception dampens or halts private-sector investment.

Policy consistency has become an issue in recent years as space business has grown and new Government agencies have entered the planning and regulating arena. Decentralization of Government agency responsibilities for operations increases the difficulty of evenly and consistently implementing policy from one agency to another, and even from one office to another within an agency. Business executives contemplating this dynamic environment must weigh the risk of meeting the requirements of one agency only to run afoul of another.

Policy Stability

Industry's willingness to invest in space commerce depends on its perception of uncontrollable risks from changes in Government policy. For this reason, achieving year-to-year policy stability should be a primary Government objective.

Commercial space policy is influenced by the political philosophies of each administration, as well as by the personal views of key Government officials. It is a

part of the larger philosophical issues concerning the proper degree of Government involvement in industry development. For this reason, successive administrations (and even successive periods within a single administration) have brought different policy approaches to space enterprise.

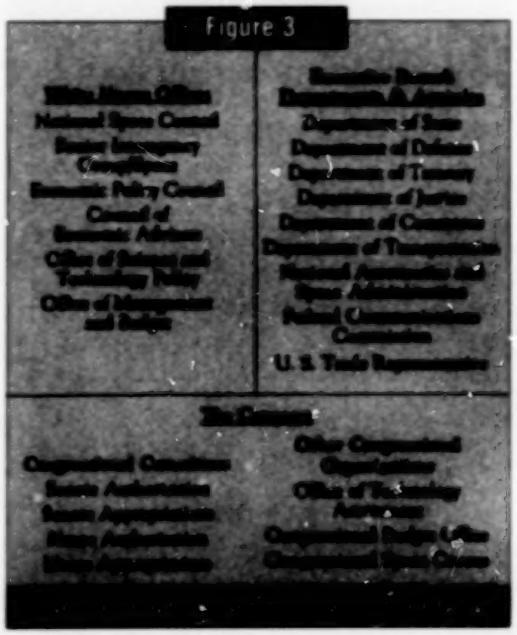
Policy Consistency

The degree of challenge inherent in implementing commercial space policy is revealed by the sheer number of agencies influencing space policy *(Figure 3)*. They fall into three broad groups: White House-related offices, executive branch agencies, and Congress.

Functions of the Government include establishing and overseeing compliance with policy, setting goals, providing and managing research and development, providing space-related services, serving as customer for some commercial space products and services, regulating, and mediating or negotiating in international matters, including trade. Each of these functions may be performed by a number of agencies, often without coordination.

Under the last administration, commercial policy formulation at the White House was performed through private deliberations of the Economic Policy Council and the Senior Interagency Group/Space. Although the Office of Science and Technology Policy participated in policy development, the absence of an overall national science or technology policy during the Reagan era handicapped Government funding of new technology development. More recently, the Office of Management and Budget has entered the commercial space policy arena by deleting the funding for specific NASA projects in the hope that private-sector companies would step forward to undertake the projects on a commercial investment basis. Although NASA remains the primary agency for space technology and infrastructure for all commercial industry segments, at least seven other Government agencies are currently involved in formulating and implementing commercial space policy.

Figure 3



The Committee's review found that the combined effects of policy inconsistency and instability have been responsible for nearly 50 major changes in U.S. commercial space policy over the last 30 years, affecting all sectors of space industry:

- Satellite communications policy changed 34 times in 30 years.
- Space transportation policy changed 5 times in 10 years.
- Space infrastructure policy changed 5 times in 6 years.
- Space manufacturing and processing policy changed 3 times in 8 years.

The following examples from the satellite communications and space transportation industries illustrate the adverse effects of policy instability and inconsistent application.

Satellite Communications Policy

Between the Eisenhower and Reagan administrations, the policy on Government funding of advanced research and development for satellite communications technology shifted five times. One of the most significant shifts was from the Carter administration, which initiated the Advanced Communications Technology Satellite (ACTS) program, to the Reagan administration, which repeatedly tried to cancel it. During the Reagan administration, because of a fundamental disagreement between the White House and Congress, funding for the ACTS program was eliminated five times by the White House and restored each time by Congress. During the same interval, Federal policy on aeronautical satellite communications changed eight times, and policy on mobile satellite communications shifted five times.

These frequent policy changes have created an unstable regulatory environment for fixed and mobile satellite communications, and have sent mixed signals to industry about the future availability of applications technology and communications markets. Uncertainties and delays in the ACTS program, and progress in that field in Europe, raise questions about America's technology lead in the international communications satellite market and suggest a need for a careful assessment of the adequacy of the U.S. Government's technology development program in satellite communications.

Space Transportation Policy

Up to 1986, Government policy provided for carrying all U.S. payloads (including DOD and commercial satellites) to space on the Space Shuttle. Thus, during the period of 1981 through 1986, Government expendable launch vehicle programs were being phased out. Then, in 1986, following the grounding of the Space Shuttle, President Reagan removed commercial communications satellites from the Space Shuttle to prevent future Government competition with the nascent commercial expendable launch vehicle industry.

Although the policy shift proved beneficial in starting a new commercial expendable launch vehicle industry, it damaged the Shuttle-dependent (upper-stage) commercial launch industry (including privately developed transfer vehicles such as PAM [Payload Assist Module] and TOS [Transfer Orbit Stage]) by eliminating the commercial market. Other negative effects included major disruptions to communications satellite manufacturers and operators — who had to find alternative, more expensive space transportation — and a considerable boost to foreign launch vehicle providers — who no longer had to compete against the arbitrarily priced Space Shuttle launches.

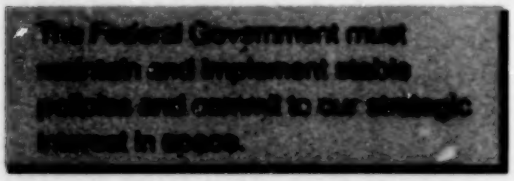
Policy Leadership

Establishing a competitive edge in commercial space businesses, as measured by established revenues and a growing market share, should be a major goal for U.S. national leaders. To do so, direct endorsement and visibility from the President and executive branch are essential. Further, a single official at the administration level should be designated to coordinate, in consultation with industry, national commercial and civil space efforts. This individual would be responsible for establishing goals and priorities with a competitive thrust. In addition, each implementing agency needs its own clear assignment of responsibility, authority, and accountability

with an adequate budget to fulfill its space-related roles.

The Missing Voice

While Government organizations with an interest in commercial space policy continue to proliferate, the private sector has been absent from actual policy-formulation deliberations. Although individual agencies have formed industry advisory groups, these groups have not had any direct input to decisionmaking at the national level. Even the recent actions to earmark for private-sector development certain projects that were previously within the NASA budget were taken without private-sector consultation.



International Investment

The international aspects of space commerce introduce additional complexities into the assessment of market potential and investment risk:

- Intellectual property protection — mutual protection of interests among companies may now be fairly common, but protecting data across national boundaries is more complex and subject to greater risk.
- Multiple legal jurisdictions — different national laws and standards of enforcement introduce considerable doubt over the endurance of agreements, the ownership of proprietary products and data, and the likelihood of equitable dispute resolution.
- Export controls — the extent and enforcement of export controls on space-related services and technical data vary among countries. Companies that must deal with stricter national export controls and more cumbersome procedures are at a disadvantage in international markets. U.S. technology-transfer controls require simplification and better interagency coordination.
- Nontariff trade barriers — already a handicap in other economic sectors, nontariff barriers, such as national standards, can frustrate efforts of a space enterprise to export across barriers. International agreements must be negotiated to overcome such barriers.
- Extended investment and payback periods — American investors often look for quick returns, which are not a feature of space-related ventures with their inherently long gestation periods. This investment philosophy puts U.S. commercial space enterprises at a disadvantage when they compete against foreign space ventures that are largely government-owned or that receive substantial government subsidies.
- International finance — currency fluctuations, the intrusion of public investments, and other variances add risk to equity investments and commitments in long-term projects involving multinational deals.
- International political considerations — international cooperative undertakings must take into account changing and conflicting political interests when sovereignty-related issues are at stake. Remote sensing may well prove to be an important application where international cooperation will benefit all parties.

These and other aspects of the international space business environment require careful consideration and planning when an entrepreneur considers launching a venture in a field with international markets.

Competition or Cooperation

The development of foreign commercial space capabilities is a central issue when examining how the international environment affects U.S. commercial space businesses. International commercial space markets will become very competitive because foreign space programs place great emphasis on achieving a commercial market share and a competitive advantage. In contrast, only a small fraction of U.S. space efforts are commercially oriented today. At present, foreign commercial space efforts are better focused and organized than their U.S. counterparts, which are already losing market share to foreign interests in such critical sectors as launch services and remote sensing.

In today's budget environment, it may not be feasible to pursue market leadership in every space sector. Strategic decisions are needed on which markets to support and develop. Markets to pursue must be selected according to their strategic value and their potential to develop private-sector competitiveness with minimal budget impact.

Several agencies implement foreign trade policy, including the Departments of State and Commerce, and the White House Office of the U.S. Trade Representative. Where space is involved, NASA also has substantial foreign contact, some of which has trade implications. Coordinated trade studies involving these agencies should be conducted regularly to identify appropriate, unified courses of action in various space commerce sectors, to provide a rational basis for decisions on whether to compete or to form Government or private international cooperative ventures, and as a basis for negotiations. Industry consultation and input will enhance the value of such studies.

Detail of *Max-Q*, watercolor by Chet Jezierski

Competing internationally is not always the best course. The United States must also consider areas for international cooperation. Exploiting space for commercial purposes is a costly endeavor, and mutual interests may be served through collaboration. Government leaders must identify, in concert with industry, areas where cooperation makes sense.

Space projects for which international cooperation is particularly advantageous to the United States, either on a government-to-government basis or on an international industry basis, are characterized by very large scope and high cost; the opportunity to leverage the cooperation into prestige, leadership, political, trade, or foreign policy advantage; the need to integrate foreign technology not available otherwise on a timely basis; and the need to overcome sovereignty obstacles. Some examples for possible cooperative endeavors include Space Station *Freedom*, already in progress with substantial participation from ESA, Japan, and Canada; the Mission to Planet Earth,

an environmental charting project of the International Space Year in 1992 planned to involve a multinational system of satellite and data-collection systems; the establishment of a lunar base proposed by President Bush; the planned manned expedition to Mars; an international Earth-observation system; satellite navigation and geopositioning; and emergency beacon monitoring. Although many of these endeavors will necessarily be initiated as Government programs, each has potential for private-sector initiative, investment, and commercial participation. Other projects are already the subject of multinational industrial teaming.

U.S. participation in large international projects may facilitate access to and evaluation of foreign technology, thus helping to accelerate and focus U.S. technology development programs. An understanding of the progress and goals of foreign research efforts is needed to assist U.S. industry in decisionmaking and goal setting. In addition, a technology conversion program is needed to accept cooperatively developed technology and accelerate its conversion into commercial products and services.

In addition, international cooperation on space projects often plays a role in U.S. foreign policy and international prestige. A specific space program may be used as a tool to promote U.S. policy. The Soviet Union makes extensive use of its space program to build and strengthen relations with Western and third-world nations.

Access to Space

Frequent, reliable, and economical access to space is critical to stimulating commercial space markets. Until low-cost space transportation and low-cost hardware and facilities for on-orbit research and operations are available, commercial space activities will be limited.

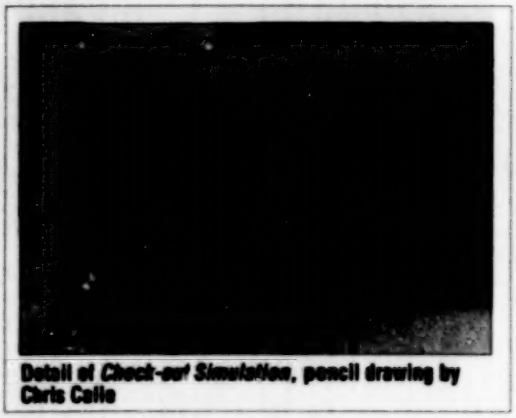
The newly formed commercial space transportation industry currently consists of relatively costly expendable launch vehicles (based on military designs from the 1960's and 1970's), several smaller, newly developed systems, and sounding rockets. The overburdened Space Shuttle program is no longer available for commercial launches except for Shuttle-unique payloads. Foreign transportation providers have an economic advantage in this market because they have government support, subsidies, and low-cost labor supplies. U.S. Government encouragement and support for American transportation providers, and purchases of the services they offer, are important first steps in creating a more equitable and competitive situation.

Commercial User Needs and Technology Development

The space access issue goes beyond the competitive posture of the launch industry. The availability of transportation is strategically important to all commercial space development. For example, developing new products in microgravity depends on the opportunity to conduct research in space. Frequent, low-cost access to space and orbiting facilities is essential to performing the experiments needed for product development.

Commercial interests will need the infrastructure provided by the Extended

Duration Orbiter (a modified Space Shuttle), Shuttle payload bay pressurized modules, Space Station *Freedom*, and free-flying platforms to explore fully such space environment opportunities as microgravity research and commercial material processing. Although industry may increasingly be a customer for (as well as a provider of) Government infrastructure and transportation, commercial user requirements have generally been given only secondary consideration.



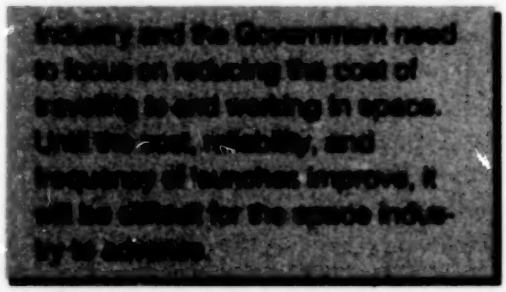
Detail of *Check-out Simulation*, pencil drawing by Chris Calle

Government investment in technology for low-cost space transportation will be needed to help meet private-sector transportation needs, not just NASA and military requirements. Program goals should also encourage the development of innovative technology and ways to reduce cost through operational efficiency or streamlined production. For example, the Advanced Space Technology Program of the Defense Advanced Research Programs Agency (DARPA) has invested about $80 million over three years to support the development of two new-technology launch vehicles and several "lightsat" spacecraft to pursue advanced device- and subsystem-level space technologies, and to build and test new types of satellite ground-control stations. Most of the work is being performed by small companies.

In addition, international standards for launch vehicle components, docking systems, and payload interfaces would be a positive step. These should be standardized interfaces as opposed to standard systems. The concept of interchangeable parts has always been an integral part of industry activity and should be introduced as a useful development for commercial space.

Significant reductions in the cost of space transportation are not likely for at least 10 to 15 years. Accordingly, it will be important for the Government and industry to work together to solve the need for reasonably priced access to space through methods such as special pricing and deferred payment arrangements.

Lastly, single-point failures must be eliminated. The U.S. space program stagnated after the *Challenger* accident and a series of other launch vehicle failures. It makes sense for the Government to develop or support industry development of alternative transportation modes in addition to improving existing systems. Clearly, a strong, responsive, mixed fleet is essential.



Technology and Product Development

One traditional model of the U.S. commercial product development cycle is a linear progression that draws on basic science and proceeds from new technology development to applied

technology to product development and, ultimately, to market introduction. Today's world moves too fast for this process to be as effective as it once may have been. In the current competitive environment, new technology rapidly surpasses the old, challenging the players to adjust and respond. As a result, the Government and industry must cooperate in identifying and developing useful enabling technology that is driven by market demand. This selective effort will enable the United States to adapt quickly to changing market needs and bring new products to market at a faster pace.

The conversion of science and technology to products and services should no longer be limited to a linear path. This conversion must be an interactive, collaborative effort among the Government, academia, and industry based on a thorough understanding of market forces and foreign technology capabilities.

Through this collective insight, the Nation can fully apply public and private resources to identify and develop enabling and core technology with the greatest potential benefits to the economy. In the space industry, this process involves establishing a better communication link between NASA and industry so that NASA can fully understand industry's interests and requirements.

As a source for innovation, the Small Business Innovation Research (SBIR) program provides incentive to small business entrepreneurs to innovate; it also strengthens the role of small business in meeting Federal R&D needs. The U.S. Government should embrace the SBIR program as a mechanism for stimulating space research that is geared toward achieving commercial goals or advances in enabling technologies. A portion of the program, however, should be focused on private-sector space needs — not just on supplementing NASA or defense R&D requirements. Additional emphasis should be placed on assistance in developing viable business plans and obtaining private financing during the research phase of the SBIR program. This change would limit the current use of the program as "grant" money or supplementary R&D funding as well as accelerate the drive toward commercial development of space industry.

One method for enhancing the relationship between the Government and the private sector is through programs like the Centers for the Commercial Development of Space. This NASA program, if properly focused on the productive conversion of new technology and science to industry-relevant products and services, could provide a unique forum for the Government, academia, and industry, and could become an effective and essential tool to increase U.S. technological competitiveness.

But caution must be exercised in programs like the centers because the conflicting goals and cultures of industry, academia, and Government organizations can erect barriers that hinder the program's original intent. One important step to ensure success is to make the program results-oriented. Sound productivity criteria could be established so that, after a startup period of perhaps three to five years, continuation of Government support would be linked to useful output as measured by industry use in commercial application.

Another way to encourage direct industry participation and accelerate the technology transfer to industry is to introduce an industry principal investigator exchange program. Thus, a qualified scientist or technologist from an industry

affiliate of a center would be assigned to work full- or part-time for a period of perhaps one year at the center, bringing industry interests to bear on the selection and conduct of development projects. In exchange, a center staff member might work in the industry setting, gaining insights on practical application of the center's experimental work.

In addition to improving the effectiveness of technology conversion by the Centers for the Commercial Development of Space, the spectrum of technologies addressed by the centers should be expanded to include communications, low-cost transportation, and infrastructure (low-cost hardware and operations support).

Many classes of potential new space products are expected to be derived from materials produced in the low-gravity environment of space. One obstacle to market development for material produced in space may be the lack of experimental data on the practical value of such material. For example, gallium arsenide and mercury cadmium telluride can be produced in large, well-ordered crystals, thus far superior to terrestrial crystals. Both materials have applications in high-speed, high-sensitivity electronics and sensor technology. But there is a need for applications engineering to establish whether the performance of the higher-quality space-based material delivers superior performance in the manufacturing process or in operation to justify its higher cost. Similar questions apply to space-based alloys, polymers, and organic materials that can be made better in space, or can be made only in space.

Government sponsorship, perhaps by DARPA, the National Institute of Standards and Technology (NIST), or the NASA Centers for the Commercial Development of Space, may be appropriate to support the exploration of applications. Positive results should be widely promulgated to U.S. industry. Full use should be made of all obtainable Soviet data on the applications technology of space-based materials. Market development should also follow expanded work on applications development to make use of the special qualities of space-based materials.

Complementing the need for rapid and targeted technology conversion, the Government and industry must develop the ability and resolve to support long-term investment in far-reaching, strategic objectives to avoid falling victim to the pressures of the quarterly balance sheet or annual budget appropriations cycle.

Industry needs added incentives to develop space technology in cases where specific applications may require extended development.

Markets

Commercial markets for most space products and services have yet to materialize. Currently, the active space market sectors are satellite communications and, to a lesser degree, transportation and remote sensing (the latter being still quite tenuous). Although the commercial satellite communications market is well established, the transportation sector (commercial launch vehicles) is just starting commercial operation in 1989, with six commercial launches of McDonnell Douglas Deltas, Martin Marietta Titans, and General Dynamics Atlas Centaurs scheduled during the year, as well as launches of several smaller sounding rockets. New markets will not emerge overnight; they must be nurtured and developed.

One primary cause for slow market growth is the lack of data for product development. The success of commercial space depends on the ability to market successfully new space-developed products that have a high economic payoff, thus warranting the high transportation and development costs. Until significant commercial demand develops for space-related products, services, and processes of extraordinary commercial value, the U.S. Government will continue to be the primary customer. High-yield products must be identified and developed, and a market for each must be cultivated before a true commercial sector can emerge.

Innovative products and services are one path to building commercial space business. Examples of new space businesses now generating revenues through such creative approaches include the following:

- Geostar Corporation and QualComm Corporation, which provide satellite-based digital message service, geo-positioning, and asset tracking for customers such as the operators of highway transport fleets;
- Orbital Sciences Corporation, which builds upper stages and the Pegasus launch vehicles; and
- StarNet Structures, which is developing unique structural systems for structures to be assembled in space.

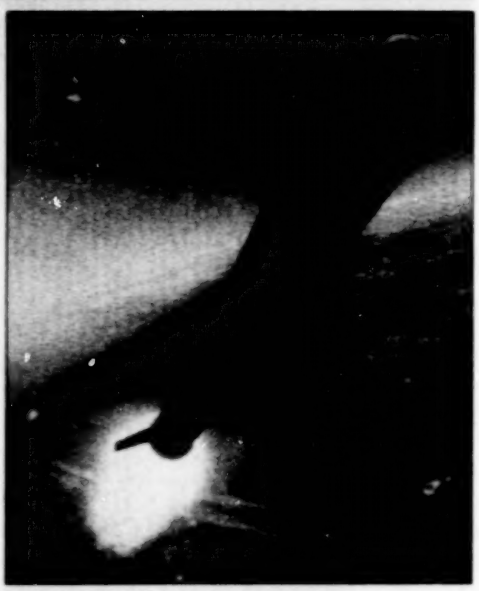
For the commercial sector to become viable, issues concerning infrastructure and access to space must be addressed. Private-sector involvement in infrastructure requires extensive capital outlays. Investors need to be reasonably certain they can profit from their investments and therefore require reasonable assurance that a market exists. Commercial users in potential markets are reluctant to invest funds in space research facilities, so they sometimes join the ranks of the user community for commercial infrastructure.

Clearly, this is a chicken-and-egg situation, which is compounded by competition from foreign government-industry teams pursuing the same few potential customers. But in attracting investment, it is important that projections of need and markets be realistic; overselling in a technology-push situation will undermine investor and public confidence. This situation sometimes leaves only the Government, in some cases a foreign one, as the initial anchor tenant until risk of access and cost can be demonstrably reduced. By accepting the anchor-tenant concept, the Government can reduce market risk to private providers who can then obtain needed financial resources.

The Government as a Customer

If the Government is to procure commercial space services and accept private proposals, procurement reform needs to be addressed. Current requirements could stifle innovation and private risk taking, partly because companies fear losing trade secrets or competitive advantage when their innovative sole-source proposals are converted to broadly disseminated competitive procurements. Reforms might include the following measures:

- Broadening guidelines for accepting unsolicited and alternative proposals,
- Providing for positive protection of proprietary intellectual property,
- Obtaining authority for multiyear appropriations,
- Streamlining competitive procurements,



Pegasus (Orbital Sciences Corporation)

- Providing adequate liability coverage for contract termination, and
- Introducing commercial practices into the procurement process.

Examples of the latter include specifying functional, but not firm, design requirements and requiring less voluminous proposals. A study group of the Department of Transportation's Commercial Space Transportation Advisory Committee, an industry body, is examining model procurements for possible application to the Medium Launch Vehicle procurement, as well as for future launch vehicles and satellite procurements.

Outreach

The private sector must become more aware of the commercial potential of space and the various ways companies can become involved. A coordinated outreach effort and a center program that links technology centers throughout the country can generate this heightened awareness.

As an element of its outreach activity, NASA provides information on commercial space opportunities to interested companies and individuals. NASA currently has several forms of agreements that offer incentives by providing for free or low-cost launches, deferred payments, and opportunities to conduct research. These programs are invaluable in the early market development phase and should be continued. Improvements can be made, however, in the priorities for manifesting industry payloads on the Shuttle that now are often delayed as much as five years.

In the near term, the U.S. Government must be willing to encourage market development through the use of direct support, anchor-tenant roles, outreach programs, agreements for the use of NASA facilities and flight opportunities, and through commercial centers. With current budget constraints and limited resources, the Government and industry must work together to identify user and provider markets with the greatest strategic potential.

In the long term, non-U.S. Government users must emerge to sustain the industry. Until this market materializes, the Government and industry must work together to develop the market.

Capital Formation

Although many factors affect financing for commercial space ventures, the lack of large established markets is the most critical. In the long term, viable user markets must be developed if the commercial space industry is to be successful. In the near term, the Government and industry must develop commercial markets by sharing risk and providing the necessary incentives to attract users and private capital. In the absence of vibrant commercial markets, the Government is an important force in fostering commercial space initiatives.

Risks for ventures fall into several categories: political, technical, schedule, contractual, market, and financial. Much of the political risk can be eliminated through leadership and organization. Through increased emphasis on guaranteed, reliable, frequent access to space, much of the schedule risk can be attenuated. Similarly, the market, technology, and product development programs already described will alleviate some technical and market risks.

Even with these initiatives, commercial space ventures still have plenty of inherent or uncontrollable risk. Given all the uncertainties and lack of defined markets, traditional financing sources are reluctant to sponsor space-related projects, or they do so with terms that may not be in industry's best interests. A 50 to 60 percent return on investment might be required to meet investors' risk-return criteria. Achieving this level of return means the Government, as the dominant near-term customer, must pay high prices and the price threshold of other potential users may be exceeded. Therefore, several innovative risk-reduction concepts need to be applied to reduce the financial risk.

Capital Through Risk Sharing

New commercial space ventures may begin as projects within established corporations, joint ventures (including multinational projects), or as research projects that evolve as new-start space companies. These ventures, which must move through several phases toward successful maturity, may require funding in many forms.

One innovative concept would be to develop a funding arrangement based on risk sharing, with the funds committed to a strategically selected project (the selection criteria being based on economics, national interests, competitiveness, or other concerns). The risk-sharing concept would require the Government to absorb some risk, the investor to absorb some, and the industry partner to absorb the remainder. The deal would be structured so every party not only shares in the risk but has a vested interest in the success of the project and ultimately shares in the rewards.

Research and Development Incentives

Another innovative incentive concept would be to create a substantial R&D tax incentive, such as a permanent R&D tax credit, for space projects. Without defined markets, it is difficult for industry to invest in technology development unless there is additional incentive. Because most space projects are in the R&D stage, R&D tax credits would accelerate the growing interest in space by channeling money into technology and market development. Similarly, a special capital-gains tax reduction would be a useful incentive.

Insurance

The third concept for reducing financial risk deals with insurance issues. The unavailability of insurance has limited the ability of companies to obtain debt financing. This problem could be overcome if the Government were to act as a bridge guarantor for the debt until insurance becomes available or were to purchase insurance (instead of self-insuring) for many of its missions. The latter solution would not only increase the pool of funds available for insurance, but would also introduce stability into the

insurance business, leading to reduced costs for users.

Third-party liability is also an issue. Given the high cost and complexity of space systems, the potential liability to industry and investors will prevent investment in many cases. The Government should consider capping third-party liability. The limit should be set at a level at which the Government and industry share risk within reason. Third-party liability is a critical issue in infrastructure development, transportation, and new products and services.

Tiered-Pricing Policies

A final way to offset the unusually high risks of space ventures would be through prudent pricing policies for Government resources such as the Space Shuttle and KC-135 aircraft for brief parabolic, low-gravity flights. It would be helpful for NASA to develop a two-tiered pricing policy to provide a price break to startup U.S. space industries.

Government price incentives should be geared to the development stage of the project. The current pricing policy evolved from the one-time launch of communications satellites. But it is not reasonable to assume that all markets are mature enough to justify the same transportation costs that are reasonable for the communications market. Other areas such as material processing, where early research is required, should be eligible for reduced rates because the risks and market uncertainties are too great to warrant the high transportation costs.

In addition to offering reduced rates, it would be useful if the Government purchased launch services or commercial rockets on a quantity basis and resold them to qualified startup firms at reduced rates.

Infrastructure-related areas that require frequent access or continuous operation should be eligible for a different pricing policy. The price should again be determined by the maturity of the market and the risks involved in the venture.

In the short and long term, funds must be available and accessible to finance commercial space projects. Given the high risk and large capital requirements, and traditional sources of funding with more attractive alternative investments, businesses are reluctant to invest. Ultimately, the solution is a combination of risk reduction, risk sharing, cost reduction, and Government commitments as a customer.

Industry-Government teamwork is essential to launching the commercial space industry. This strategic partnership is a critical step in developing a competitive advantage in certain space markets. It also provides a means for ensuring leadership, generating a positive trade balance, and maintaining technology and economic superiority — or at least parity — in future markets. The real boost to space industrialization is in cooperative industry-Government initiatives geared toward increasing America's ability to compete in global markets.

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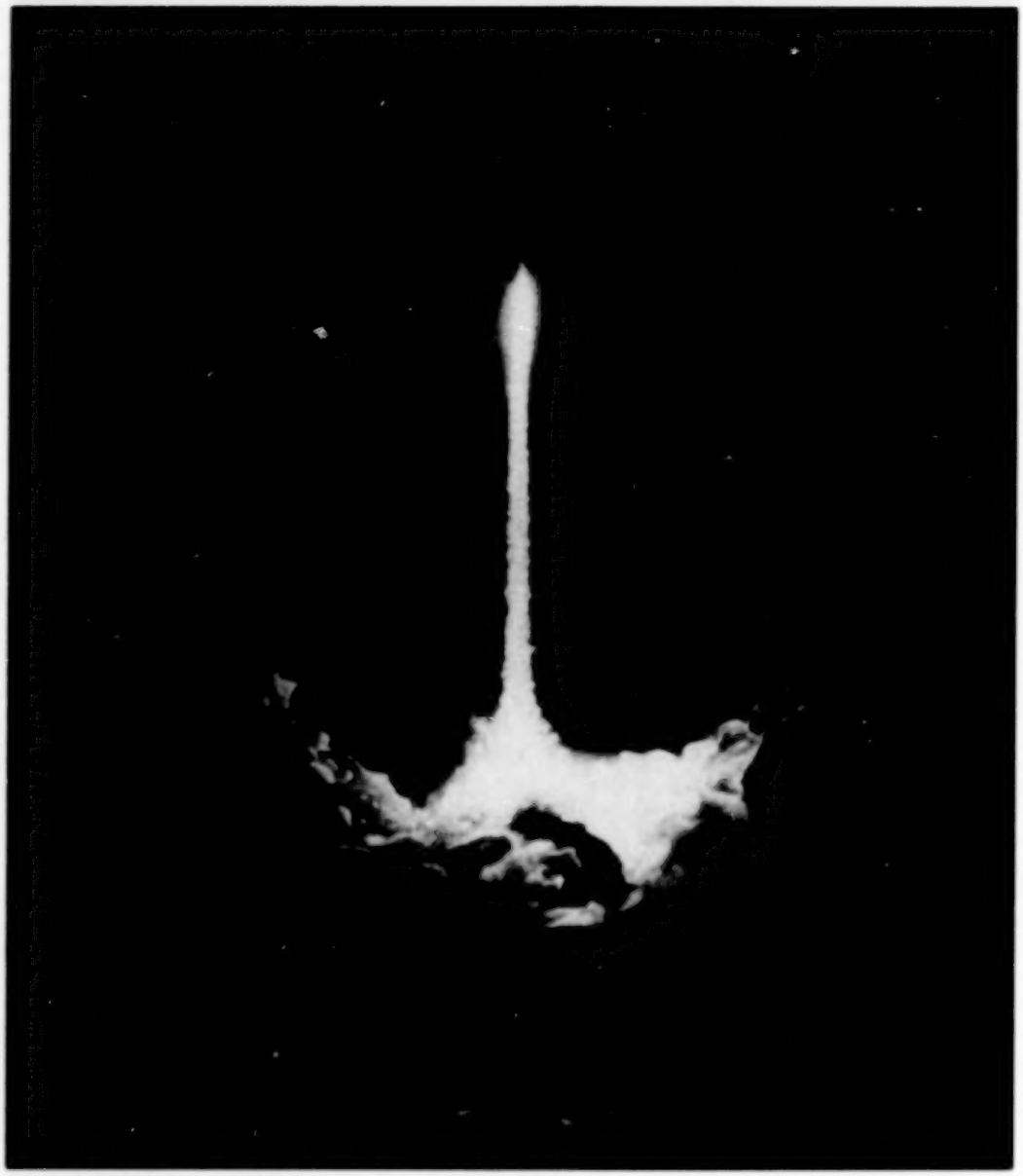


Detail of *First Night Launch-STS-8*, acrylic by Andreas Nottebohm

During the Apollo era of the space program, the United States could proceed at its own pace in space pursuits. Because of U.S. dominance in space, the Nation could achieve space goals and accommodate new technologies as they emerged, with few fiscal, political, or schedule constraints, and with remarkable success.

The Space Shuttle era brought increasing budget constraints. It also brought the beginnings of a marketplace flavor, as NASA launched payloads for worldwide commercial interests on a reimbursable basis. On the fifth Shuttle flight in 1982, NASA launched two communications satellites, SBS-C for Satellite Business Systems and the Canadian Telesat-E. By then, satellite communications had emerged as the first real space market sector, with COMSAT, originally a

congressionally chartered corporation, prominent in serving a market that already existed in terrestrial form. Spinoffs were of interest, but competition was not a factor.

This is no longer the case. The development of foreign commercial space capabilities is a central issue in the future of U.S. commercial space-related businesses. Space businesses take many forms, from units of major aerospace and communications corporations and conglomerates to dozens of small new-start space enterprises. Today's overseas efforts are better supported by their governments and often better focused and organized than their counterparts in the United States. As a result, the United States is already losing market share to foreign interests in several critical space business sectors, notably launch services and Earth observation. Individual U.S. firms are unable to keep up with the commercially oriented space technologies being developed and taken to market by foreign space programs.

Unless the United States revitalizes its approach to the commercial development of space, America will be unable to compete successfully. The United States risks becoming a secondary player in this emerging sector of the future world economy, with ominous implications for technological leadership, the balance of trade, and influence in foreign affairs.

The Role of Government

Throughout the Nation's history, the Government has motivated and aided new industries, particularly in utilities, mail services, railroads, and civil aviation. Typically, the roles of the Government and industry vary over time as industry develops and matures, with the greatest level of Government support needed in the critical early phases of an industry, when many doubt its value and prospects, and when risks (or perceived risks) are greatest. But in each historical case, the industry or system aided has proved to be of significant benefit to the Nation's welfare and economic success, and its competitive posture in the world.

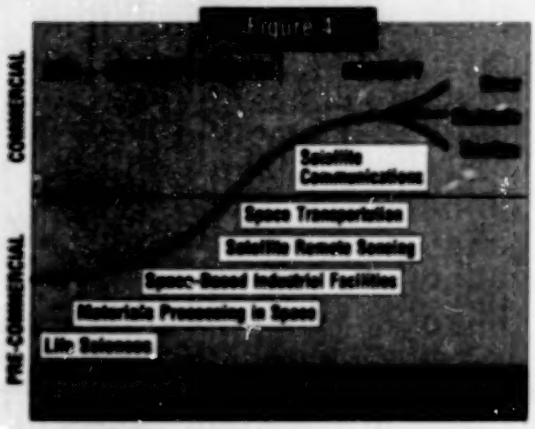
Two Presidents have acknowledged the economic potential of space technology and access, but the priority assigned to its realization and the extent of the Nation's efforts do not measure up to those of America's commercial space rivals in foreign countries. The White House space policy released in February 1988 spoke of "creating opportunities for U.S. commerce in space," but the opening words of the policy on encouraging a commercial sector in space, "that the Federal Government actions shall not preclude or deter the continuing development of this sector," probably best characterized official national resolve at that time. Early statements by President Bush suggest his administration is interested in private-sector space initiatives. Funding support for the Government's role is not yet established.

The relationship between technology (including space technology) and national competitiveness strongly suggests a need for a more activist Government role in nurturing this new commercial aspect of U.S. space activities. Broadly, three levels of Government involvement might be considered:

- **Minimal involvement** — if the Government assumes the traditional role of relying on market forces with minimal involvement and meeting its needs through traditional procurement to specifications, then U.S. companies will not be able to compete successfully against heavily subsidized foreign

government-industry partnerships in many space-related markets.

- **Heavy involvement** — if the Government assumes the untraditional approach of heavy involvement in space-related commercial competition, then many other factors will change. Government budget pressures will worsen, risk-reward perceptions will be dramatically altered, and attitudes toward investment ownership of data will change. This level of involvement is unlikely and probably not appropriate for the U.S. economy.



- **Moderate involvement** — if the Government assumes the most likely role of moderate but positive, activist involvement, then appropriate roles must be defined so commercial interests can plan accordingly. These roles must be sorted out swiftly and clearly to create an effective, more cooperative Government-industry relationship. For example, NASA could play a key role in developing technology for low-cost satellites and transportation in a manner similar to DARPA's as described in Chapter III under "Commercial User Needs and Technology Development." The roles of individual agencies must also be defined to make jurisdictions over, and relations with, industry clear-cut. Overlapping and conflicting agency jurisdictions and orientations must be addressed as well.

Although national budget concerns will preclude heavy Government involvement in the near term, a substantial increase in active support is needed if the United States intends to be a prominent player in world space markets.

Although a supportive national environment, including stable, supportive policy, should be a continuum, the specific level of support the Government should provide to the development of private-sector space activities depends on the state of maturity of each space market sector, and of specific space enterprises in the sector. That is, more support can be justified for a qualified sector or venture in its early stages than when the business is accruing revenues.

An examination of the phases in the space business development cycle, as illustrated in *Figure 4*, is useful. For each phase, the space business sectors currently characterizing that phase are given as examples along with an indication of market outlook and appropriate Government support. The space business sectors used in this discussion are as follows:

- Satellite applications — satellite communications, geopositioning and asset tracking, satellite remote sensing (or Earth observation);
- Space transportation;
- Space infrastructure; and
- New products and services — materials processing in space, and life sciences.

Research and Development or Startup Phase

Examples of space businesses in the earliest, or R&D, phase concern microgravity phenomenology. Potential business areas will probably involve materials processing in space and life sciences. At this time, activities consist primarily of research performed in low gravity (mostly in Earth orbit in the Space Shuttle) to obtain scientific data leading to production of high-value materials on orbit or significant enhancement of terrestrial materials.

For example, in a recent survey of the biotechnology industry by the Center for Space and Advanced Technology, a substantial majority of the respondents indicated that space research is of value to the biotechnology industry. No products are yet in production, but ongoing work may lead ultimately to a wide range of new products from materials such as protein crystals (of keen interest to the pharmaceutical industry in its research to develop new drug treatments); electronic substrate materials for high-speed, high-sensitivity sensors; organic crystal-based semiconductor materials for electronic circuits; polymer and metal alloy products with characteristics superior to terrestrial products; and ionic catalysts using such space-based materials as large, perfect crystals of zeolite.

In the near term, the value of microgravity research lies not so much in space-based products as in the new knowledge of molecular structure, crystal growth, material properties, and life sciences that can help solve problems facing science and industry on Earth. For example, McDonnell Douglas's pioneering work in continuous-flow electrophoresis in Earth orbit is considered to have fostered the genetically engineered terrestrial production of erythropoeitin (or EPO). EPO is a hormonal substance that stimulates red blood cell formation for the one-shot treatment of dialysis patients, which is expected to go on the market in 1989. It has a potential market of more than $1 billion.

Researchers in microgravity sciences agree on the need for much more research on orbit, some of it of the longer durations that will be possible on the planned Extended Duration Orbiter, on Space Station *Freedom* when it becomes operational, and on unmanned free-flyer platforms that might co-orbit with the Space Station and provide a low-gravity environment of a higher order (up to 10^{-6}g) than manned vehicles can offer.

Cumulative U.S. low-gravity research is measured in man-weeks, while the Soviets have accumulated several man-years of orbital research. (The National Academy of Sciences estimates the Soviets have performed more than 1,700 microgravity experiments in Earth orbit; the U.S. count is less than 200.) Although U.S. knowledge of the value of this Soviet research is far from complete, it is clear that much more research is needed. But industry cannot underwrite the cost without substantial Government support in access to space, shared research, infrastructure, and monitoring of experiments by astronauts.

Although more than 100 possible products and product categories have been identified — and patient populations and high-value demand have been calculated for space pharmaceuticals such as the much-desired cures for diabetes, cancer, and viral diseases — no space-based products have reached the point where useful marketing projections can be published. But scientists in a wide range of fields, supported by numerous universities and industrial firms, have committed substantial

resources and talent with the conviction that the potential is considerable.

An even greater commitment to the future of microgravity-based products has been made by ESA, which built the billion-dollar *Spacelab* for the Space Shuttle; by the West German Government with its network of microgravity research facilities; and by Japan, which is planning a major space research lab as an element of Space Station *Freedom*. Patent applications will soon be a key measure of each country's future market prospects.

A small supporting industry is emerging in the United States to service this field of research. Small companies (and several large ones) are developing and offering research equipment, payload packaging, access to low gravity on sounding rockets and aircraft, and sample-return systems. Some of these enterprises are in the developmental stage, while a few have reached startup.

What should the role of the Government be in this early R&D phase of business development? Essentially it should be an expansion of roles that have begun to prove effective:

- Maintaining an active outreach program to inform nonaerospace industries of space's potential for commercial use and to provide guidance and assistance during early exploration of applications;
- Making the results of U.S. Government scientific research and space technology available to the U.S. civil sector in a structured data base;
- Giving initial help in planning space experiments, demonstrating them on the ground, and preparing them for space;
- Providing access to space for research, at no cost for prerevenue phases of business-oriented research;
- Establishing, under grants, centers where nonprofit consortia can perform research to develop commercial applications of specific technology areas (the NASA Centers for the Commercial Development of Space respond to this action and are described elsewhere in this report);
- Obtaining infrastructure that can be used for private-sector space research, sometimes as leased facilities or equipment;

Detail of *Night Touchdown - Challenger*, acrylic by Chris Kenyon

- Assisting in the arrangement of cooperative research, including research with foreign organizations;
- Entering into agreements with companies for cooperative research, for research space flights, and for information exchange (such agreements are important to ventures seeking financing for R&D and startup; the financial community views these agreements as an indication of the validity of the venture); and

- Most important, committing to be an early customer of the venture, when this is appropriate, to meet Government needs.

It is during this early phase that Government assistance to new space ventures is most needed, although some degree of continued support, especially as a customer, is important to the survival of the ventures. Most of the measures listed above reduce ventures' risk or need for capital and enhance chances of success. In this phase, the principal criteria for determining whether to extend such assistance are the potential of the new field or venture for technical success, market development, and subsequent growth in a true commercial market; its potential to spawn or support other opportunities; and its importance to the national interest and welfare.

Detail of *STS-4 at 09.52 sec.*, oil by Ron Wicks

Middle Phases — Early Operation and Expansion

The space transportation industry is an example of a space market sector in the middle stages of development. The expendable launch vehicle segment has progressed to the point of starting commercial operations in 1989, with first-year revenues estimated at $300 million. Although Government and commercial market potential is gradually growing, competition is intense, and the risk-return prospects are still, at best, marginal.

Also entering this middle phase is remote sensing (or Earth observation), which includes both EOSAT Company (which operates LANDSAT) and the related value-added industry, which processes and customizes raw data for end-use customers such as the petroleum and mineral industries; and the use of satellites for geopositioning and asset tracking. The NASA John C. Stennis Space Center Science and Technology Laboratory reports nine private-sector interests have committed funds to commercial Earth-observation projects.

In this middle phase, the major concerns typically are obtaining capital for expanding to full operation and developing market share and revenue. Government roles of importance in this phase are as follows:

- Becoming a good commercial customer, possibly as an anchor tenant of a space facility or as a user of services;
- Continuing to share the risk, facilitate early operations, and maintain a stable policy environment;
- Making Government facilities and infrastructure such as launch facilities and ranges available at a reasonable cost (deferred payment provisions may be allowed);

- Continuing to invest in technology that is of commercial value, but is beyond industry's capacity to fund;
- Streamlining and expediting Government regulatory and administrative actions (e.g., one-stop launch permits);
- Negotiating international trade agreements in an effort to provide a more equitable, competitive situation; and
- Providing third-party indemnification.

Mature Phase

In the mature phase, space businesses are operating routinely, with steady revenue and reasonable return on investment. In some cases, diversification, new applications and services, and further growth are characteristic. But if timely action to revitalize a mature business is not taken, the business may start to decline. Satellite communications services are in this mature phase and may remain stable without new, innovative applications.

For mature businesses, the Government may continue to be a good customer and perhaps a key tenant, but the market should be increasingly in the private sector. The Government should avoid any form of competition with mature commercial enterprises. Other elements of the Government's role in the mature phase should include the following:

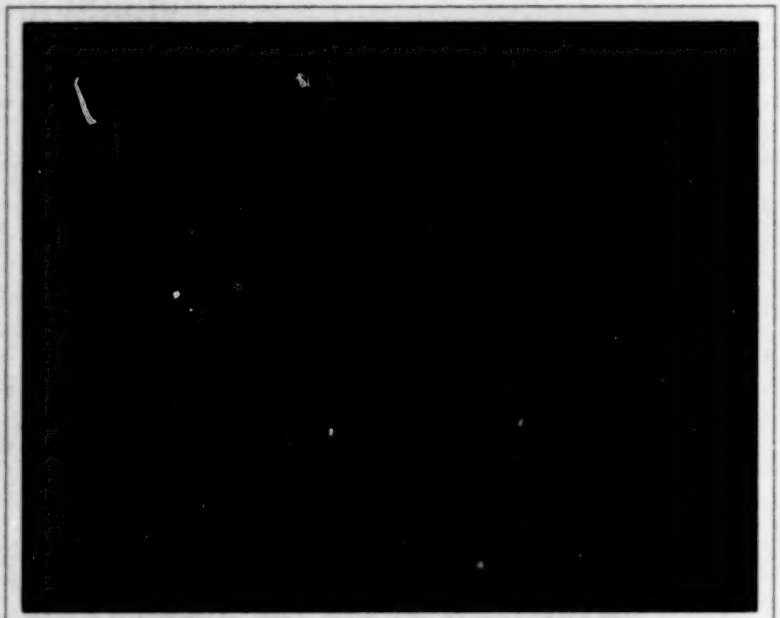
- Continuing to invest in research and technology;
- Maintaining a supportive policy, regulatory, and trade environment, and serving as mediator and regulator;
- Making Government facilities, infrastructure, and space transportation available at a reasonable cost;
- Facilitating access to foreign markets through trade agreements;
- Identifying new opportunities for industry initiatives to meet Government needs; and
- Assisting in the protection of intellectual property.

Often the interests of the various sectors of space business may be mutually competitive. In making support available for private-sector business development, it is important that the Government maintain a broad perspective and foresee interactions, both positive and negative, among sectors and businesses so that measures taken in one sector do not overburden another.

The logic of positive interaction enables the Government to take actions that, through synergism, can yield multiple benefits. In supporting private-sector research and product development in microgravity and life sciences, NASA resources may enable the leasing of infrastructure from another source business or the purchase of commercial sounding rocket launches from a third. Commercial satellite operations benefit commercial launch services (although in one instance the Government, to enhance the competitive posture of a U.S. satellite supplier, allowed launches on a low-cost foreign launch vehicle). Maintaining a broad perspective on such pervasive subjects as technology transfer, trade agreements, national security, and pricing can help minimize negative interactions. A well-thought-out program can result in cascading benefits to many kinds of businesses and national interests. Because of such interactions and the involvement of many agencies, central coordination and a balanced approach to the nurturing of America's emerging space industries are important.

Government Progress in Encouraging Industry Involvement in Space

The role of the Government in helping industry build the commercial sector is complex and involves many agencies. It will require substantial coordination and commitment of resources. But a good start has been made in several agencies in recent years, and the White House has now manifested interest in a coordinated effort.



Detail of *Truly at Suit Up, STS-2*, mixed media drawing by Bill Robles

NASA Efforts

NASA has made a commendable start in nurturing the commercial development of space. Public Law 98-361 of 1984 amended the National Aeronautics and Space Act of 1958 by adding,

> The Congress declares that the general welfare of the United States requires that the National Aeronautics and Space Administration seek and encourage, to the maximum extent possible, the fullest commercial use of space.

After careful study of the potential and limitations of the commercial development of space, NASA established the Office of Commercial Programs. The office is headed by an Assistant Administrator who reports to the NASA Administrator. Through this office, NASA now aids industry in understanding the potential of space and in planning research with a view toward commercial applications and the development of international commercial space markets and new enterprises. Particularly effective have been the following features of the program:

- **New opportunities to fly space experiments** — through the Office of Space Flight, NASA has set aside flights on the Space Shuttle and sounding rockets to support private-sector research with the potential for commercial development. Access to space is essential to the success of many space enterprises. Space Shuttle set-aside flights are available primarily through Joint Endeavor Agreements and the Centers for the Commercial Development of Space.

- **New opportunities through access to NASA laboratory facilities and expertise** — NASA field centers support joint NASA-industry research projects by providing drop tubes and parabolic aircraft flights to assist industry in preparing experiments for space flight. The centers also make a variety of analytical and test resources available to the private sector. (For example, Cray supercomputers at NASA field centers can be used for computational fluid dynamic simulations of new launch vehicles.)

- **Space System Development Agreements** — payments for a first-time

Space Shuttle launch can be deferred even if a company expects to generate revenue from the flight.

- **Centers for the Commercial Development of Space** — a system of 16 competitively selected centers, each initially funded by NASA, supports seven areas of development leading to commercial space applications. Automation and robotics, space materials, material processing in space, and life sciences are four examples of the supported areas. At the nucleus of each center is a university laboratory or other technical institute, supported by several university and industrial affiliates who participate in selecting areas of endeavor that suit their needs. Affiliates also provide an increasing share of the annual operating costs in exchange for the first use of research results. There are now 48 university and 183 industrial affiliates. This network of centers substantially enhances the likelihood that new space-related products and services will be identified and successfully developed.
- **Less red tape** — doing business with the Government should be easier for the private sector since NASA streamlined the processes for obtaining cooperative agreements and for submitting and obtaining action on proposals for commercially developed infrastructures. Similarly, the Department of Transportation's Office of Commercial Space Transportation has greatly simplified obtaining launch licenses.

Although NASA's Office of Commercial Programs operates on extremely limited resources, it has been quite successful, considering the priority of the Space Shuttle and Space Station *Freedom*. Commercial programs compete with NASA science programs for small experiment opportunities and with the Department of Defense, *Spacelab*, planetary missions, and the Great Observatories for large payload space.

Other NASA offices and centers have also made significant contributions to nurturing new space business. Noteworthy are the Office of Space Flight, the Office of Space Science and Applications, and the Goddard, Johnson, Lewis, Marshall, and Stennis space centers. Clearly, NASA has promising mechanisms in place for applying its expertise, experience, facilities, equipment, and techniques, and for providing access to space. With assets across the country and in space, NASA, with support from the national leadership, can form what amounts to a great national laboratory in which industry and the Government can become partners in exploring applications with commercial potential. In the early research stages, such partnerships can offset the advantage of other nations where government and industry sectors are not clearly separated.

The Departments of Commerce, Transportation, and Defense have been supportive of the commercial development of space. Although NASA is charged by Congress with encouraging the commercial use of space, these three departments also play significant roles, by virtue of specific programs or functions, in commercial space enterprise. Their support will continue to be important to the growth of U.S. space industrial competitiveness.

Department of Commerce

Through the National Oceanographic and Atmospheric Agency, the Department of Commerce operates the weather satellite system and oversees

LANDSAT operations carried out by EOSAT Company.*

The Department of Commerce's NIST is a resource to industry in areas such as robotics development, which will ultimately be important to the success of space-based processing.

In 1987, the Secretary of Commerce established an Office of Space Commerce to work with governmental and international organizations in formulating policies to support commercial space development and coordinate the activities of other Department of Commerce agencies affecting space business. The office also conducts educational programs to inform U.S. companies of the commercial potential of space.

Other involved offices include the Patent and Trademark Office, the International Trade Administration, and the National Telecommunications and Information Administration.

Department of Transportation

Space activities of the Department of Transportation are focused in the Office of Commercial Space Transportation, which was established to foster the creation and growth of the expendable launch vehicle industry, issue launch licenses, and administer the required mission and safety reviews. The Office of Commercial Space Transportation has develo[illegible] excellent relations with the space industry over the past several years, significantly simplifying the complexities faced by commercial launch companies.

This office also supports the Commercial Space Transportation Advisory Committee, which assisted the office in negotiating a model launch range agreement for commercial launches from Air Force ranges. Thanks to this effort and to the work of this office, the U.S. launch vehicle industry is off to a good start, with a substantial order book of launches starting in 1989.

Department of Defense

In such areas as low-cost, lightweight satellites, space robotics, sensors, communications technology, and new-technology launch vehicles such as Pegasus, the Department of Defense has contributed significantly to the development of commercial space technology. The department is the lead agency for the National Aerospace Plane project, which is also supported by NASA. The Department of Defense has become a key customer for several space products and services. Many new startup businesses and small space companies have participated in these activities.

The single most effective step that Government agencies have taken is to serve as anchor tenants or key commercial customers for the products and services offered by space enterprises.

State Efforts

A number of state governments are organizing effectively to develop space business programs, facilities, and industrial capabilities. Examples of interest include the following:

- Florida and Hawaii have active space development programs for establishing spaceports and supporting industry concentrations. (Florida's space research establishment involves several state colleges.)

* The LANDSAT venture, under a 1985 privatization project, is in jeopardy because of uncertain Government funding, and was one of the first issues considered by the new National Space Council, which gave it a two-year reprieve.

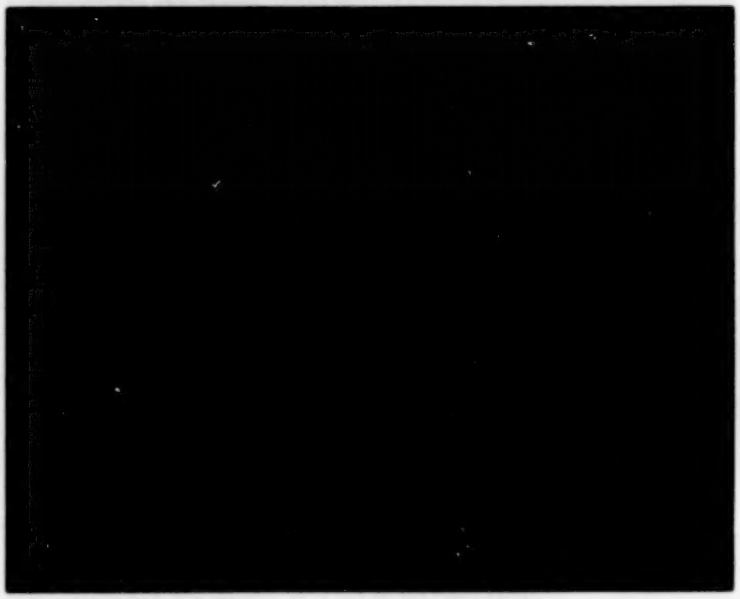
- Virginia has established the Center for Innovative Technology, now headed by former Governor Linwood Holton, to attract and develop high-tech industry. The state has organized a committee of space-related companies to assist the effort. This group is pursuing the goal of establishing a capability for private-sector launches from Wallops Island or another site, and is encouraging other commercial space-based initiatives in Virginia.
- West Virginia is actively engaged in attracting space industry by establishing research parks offering special incentives to space industry.
- Texas has an active program to encourage private-sector research in fields such as space medical technology.
- Activity also is beginning in Utah, Illinois, California, Alabama, and Mississippi.

The Committee applauds the efforts of these agencies and state governments, and urges full Federal Government and industry cooperation and support.

The Role of Industry

The initiative for developing true space enterprise must be taken by the private sector. Except for satellite communications and, recently, space transportation, industry participation in America's space program has primarily taken the form of the traditional contractor role, responding to the requirements of DOD and NASA. Considerable contractor activity will continue in Government-funded research and development, hardware manufacture, and operation and maintenance systems. Industry may play any of several roles in space:

- A traditional production or service contractor,
- A private entrepreneur or division of a corporation with a commercial offering,
- A partner with the Government,



Detail of *Challenger (In Space)*, oil mural by Jean Hierholzer

- A company taking over operation of a privatized Government space function,
- An industrial user of space-based products and services, or
- An investor in space enterprise.

Privatization refers to converting functions and systems owned or operated by the Government to private-sector operation when that is more cost effective or when broad potential for a commercial market exists. Like the commercial markets, appropriately privatized efforts have the potential to benefit the economy. In the future, industry's role in privatizing appropriate systems and services, and incubating commercial space-related markets may increase.

Commercial ventures in space today represent only a small fraction of

industry's total role in space. As new products and services are identified, markets will begin to develop, and the balance should begin to shift from Government procurement to commercial enterprise. Discovery of new scientific phenomena in the space environment, new applications for space material, and development of new, reliable, low-cost transportation systems will create additional industries, albeit years from now. Meanwhile, Government-industry teamwork is essential to bolster the commercial space industry.

Participation in space enterprise, and support of U.S. space industrial competitiveness, is by no means limited to aerospace firms. There are many roles and activities for the private sector to consider (some of which require only modest resources) that may open up new opportunities:

- Participating as an industrial affiliate in a NASA Center for the Commercial Development of Space;
- Participating in an industry council or committee that advises the National Space Council, NASA, or another Government agency as part of the national space planning process;
- Undertaking applications research using results of space-based research or space-produced materials to determine their potential for product use in comparison with their Earth-produced counterparts;
- Participating in multidisciplinary industrial consortia to sponsor space-based research;
- Sponsoring independent space-based research;
- Exploring opportunities in space commerce by tapping the scientific or technical expertise available at NASA, NIST, the National Academy of Sciences, the National Academy of Engineering, and their research centers;
- Considering a commercial initiative to provide needed commercial infrastructure to NASA;
- Examining the value to the firm's business of satellite applications (including satellite communications, remote sensing, and geopositioning and asset tracking);
- Carrying out process or product R&D under contract to a Government agency in an area that may lead to new private-sector products, services, and markets; and
- Investing in space enterprise with long-term objectives.

NASA's Office of Commercial Programs in Washington, D.C., is prepared to assist companies new to space with any of these activities.

The strategic partnership between the Government and the private sector will be a critical step in developing a competitive advantage in certain space markets. It will also provide a means for ensuring leadership, generating a positive trade balance, and maintaining technological and economic superiority — or at least parity — in future markets. Cooperative industry-Government initiatives can enhance America's ability to compete in global markets.

In addition to joint activities directed toward incubating commercial space initiatives, other joint activities can benefit both industry and the Government. As NASA plans programs, it should identify points at which industry initiatives to meet specific Government needs are appropriate, or where the Government can buy or lease commercially available space products and services. Identification of these points well in advance of the

Government's need for implementation will increase the probability of a usable response from industry and successful interaction with the private sector.

Thoughtful leaders and planners in a wide variety of U.S. industries increasingly are exploring how access to space can contribute to advances for their businesses through space-based research and new business activities based on space technology and needs.

Findings/Recommendations

Detail of *Repairing Solar Max*, oil painting by Robert L. Schaar

The ability of the United States to compete in world markets depends on the ability to develop new technology, take it to the marketplace, and establish and hold a significant market share. Where this country once held a dominant position in technology with an orderly progression from laboratory to applications and markets, it now faces aggressive international competition and uneven success in reaching the market with applications — even with its own technical breakthroughs.

Increasingly, America faces strong foreign competitors with clear market objectives for new technology and sound strategies for long-term success. In some cases, the foreign competitors are partly or totally government-owned, while others benefit from government support or coordination in their endeavors. U.S. efforts to compete in the

global market have been frustrated by inadequate patent protection and an often adversarial Government-industry relationship. Use of academic resources to support national economic development is relatively poor, and clear national objectives are lacking.

Compared to other nations, our technology is relatively open. The results are measured in a poor showing in technology market share and the balance of trade in technology products, which has steadily declined throughout the 1980's. Trends in patent count, although of uncertain validity as indices, support the finding of declining national performance. American science and technologies are excellent — but the Nation is losing the race in market applications. A recent report from the Council on Competitiveness found a variety of warning signals pointing to problems in the U.S. ability to convert technology rapidly to marketable applications.[6] It further found a lack of Federal Government focus on the commercial application of technology, and Government policies and practices have sometimes inhibited, rather than accelerated, the process.

The report noted that the Federal Government operates more than 700 laboratories, but the technology needs of industry are not among their major priorities. Only recently has technology transfer to industry come to be emphasized. The Council's report offered thoughtful recommendations for improving technology-based industrial competitiveness and urged better coordination among agencies and with the private sector. It called for increased Federal investment in the Nation's technology infrastructure, with emphasis on expediting the transfer of new knowledge from laboratory to marketplace.

The Commercial Programs Advisory Committee has concluded that, in many ways, America's position in space enterprise and the efforts needed to increase its competitive space business posture replicate the larger picture described by the Council. It is appropriate to consider, as the Committee has done, what the role of the Government should be in the early phases of this new space-related segment of the economy and in what way the Government as a team and NASA in particular can help space enterprise survive and flourish. The Committee's consideration of the issues related to commercial space, the goals proposed, the suggested roles for the Government and industry, and the urgent need to improve the Nation's competitive posture in the world form the basis for the findings presented here, which collectively provide the basis for the recommendations that conclude this chapter.

Findings

The Commercial Programs Advisory Committee believes space technology is the basis for a potentially significant new element in U.S. economic growth and competitiveness. To date, this potential has been realized only in the field of satellite communications, which is in a relatively mature phase of development. The U.S. space transportation industry will enter commercial operation during 1989, and space business sectors -- such as satellite positioning and navigation, Earth observation, and space infrastructure and services — are in developmental or startup phases. Research-phase activities are in progress relating to the special attributes of space, low gravity being the most important because it offers opportunities

for research in material processing in space and in life sciences. This research has already enhanced terrestrial processes and may well lead to important new space products and services.

But vigorous global competition will challenge all space market sectors. It is clear that spacefaring nations abroad recognize the strategic and economic significance of commercial applications of space technology, as well as the importance of access to space. Several foreign countries are operating satellite communications systems, and a few are building competitive satellites. France has aggressively marketed space transportation, capturing more than 60 percent of the free world's launch market with its Ariane series of launch vehicles. China, Japan, and the Soviet Union are also entering this market. There will be heavy competition for a limited total launch market, primarily in launching communications satellites. These nations are also moving rapidly and effectively to realize the potential of other space enterprises:

- France is a major force in the remote-sensing market, with Japan soon to follow (while U.S. efforts to privatize LANDSAT appear to be foundering).
- The Soviets, with three times America's manned space experience, have accumulated many man-years of research in microgravity; West Germany has invested heavily in this field.
- ESA, with 13 full-member nations, has well-developed long-range plans for the exploitation of space, most of which are independent of the United States.
- European companies have formed commercial consortia for the exploitation of industrial applications of space.

In most areas of space business, U.S. industry will require strong, well-coordinated Government support to reach the marketplace. Characteristics of businesses in probable space markets include the following:

- Continuing research and development;
- Considerable risk (technical, schedule, market, cost, and competing technology);
- High capital and operating costs;
- Long payback periods;
- The need for reliable, regular, low-cost access to space;
- Problems related to fluctuating Government policy, delay in decisions, and regulatory issues; and
- Budgetary and other problems related to having the Government as a key or the only customer.

In many respects, Government support to space enterprise has been commendable. The Government has recognized some of these needs. Presidential messages in recent years have emphasized the importance of developing commercial aspects of space. In April 1989, President Bush issued an Executive order reestablishing the National Space Council and creating the Vice President's Space Policy Advisory Board, a committee of private citizens to advise the Vice President on the space policy of the United States.

Congressional support has been notable. Numerous hearings have been devoted to various aspects of space businesses, and Congress has begun to provide budgetary support to NASA efforts to encourage space enterprise. As previously described, NASA and the Departments of Commerce, Defense, and Transportation have each

undertaken many constructive activities to promote commercial space. But, for Government support to be effective, space industrial competitiveness will require greater priority; strong, effective central leadership; and coordination among agencies.

Detail of *The Businessmen*, drawing by Chet Jezierski

Enhanced coherence and coordination is needed in the collective activities of Government agencies participating in the development of commercial space. Despite the positive contributions of the various departments and agencies involved, there is no strategic, central direction of effort. Industry needs an established mechanism for maintaining a regular dialogue with the executive branch, specifically in regard to overall objectives, strategies, and tactics for establishing and maintaining space industrial competitiveness.

Many of the Government's space-related functions are performed by three to seven agencies, without benefit of game plan or quarterback, on a field of tough competitors who are taking the lead in applications development and marketing capabilities. If the U.S. is to achieve a competitive position in the world, roles need to be clarified, and departments and agencies need to work together as a strong public-sector team with industry consultation.

Government support for U.S. space industrial competitiveness and space enterprise must be closely linked to leadership of the civil space program. Commercial space will continue to depend heavily on the civil and, to a lesser extent, the national security space sectors for the near term. The space policy announced by the White House in February 1988 acknowledged that U.S. space activities are conducted by three separate and distinct sectors: the two Government sectors (civil and national security) and a separate, nongovernmental commercial sector. In reality, the space market will remain dominated by the Government's demand for space hardware and services. The newborn commercial sector cannot survive without the carefully orchestrated support of the Government's civil space program. The national security space sector should also continue its considerable support to the commercial space sector.

Greater national awareness of the commercial potential of space is needed as is awareness of the significant strides being made by foreign spacefaring nations. As U.S. space business success stories surface, they should be widely told, so they will beget new undertakings and new success stories. The significance of space enterprise needs to be communicated to professionals in a wide

range of disciplines, and to the general public, through the media, the educational system, professional societies, and conferences.

Most space industrial concepts are at a very early phase of development and have suffered setbacks while America's space transportation systems were grounded. Government investments in research and teamwork with industry are likely to pay significant returns, but such returns cannot be expected on the same timetable that applies to terrestrial projects while private-sector access to space remains limited. Clearly, there are ways in which the Government and industry can work together to make space enterprise more financially feasible.

Key Recommendations

In the belief that space represents an important opportunity for the Nation's economy, welfare, and prestige, that an effective approach to space industrial competitiveness is urgently needed, and that, given the current stage of private-sector involvement, space enterprise needs continued nurturing by the Government, the Committee offers nine key recommendations. These are supplemented by additional recommendations in four functional areas: policy stability and consistency, international competition and cooperation, finance and private-industry incentives, and public and political opinion. The key recommendations are as follows:

Leadership and Goal Setting

The President, the Vice President, the Secretary of Commerce, and the NASA Administrator should publicly and vigorously endorse the development of space enterprise and space industrial competitiveness as national goals. Leadership emphasis on such national goals will assist in communicating the opportunity, significance, and priority of space industrialization to the entire public-sector team, to the industrial community, and to the Nation. This endorsement should include full Government support for the use of NASA's expertise and centers as a "national laboratory" to assist space enterprise in the research phase of commercial space industry development.

Leadership for civil and commercial space in the executive branch should be centralized under a single civil space authority — the Director of Civil Space. The President should appoint the NASA Administrator (a member of the National Space Council) as Director of Civil Space to coordinate the civil and commercial space activities of all departments and agencies involved in such activities, principally those of the Departments of State, Commerce, and Transportation, NASA, and the U.S. Trade Representative. Thus, the Director of Civil Space could draw on NASA's extensive space resources, technology, facilities, infrastructure, laboratories, and space systems to lead the public-sector team in formulating and pursuing, in concert with industry, a set of unified long-term goals for national space industrial competitiveness. The Director of Civil Space would have a small support staff drawn from the various departments and offices and would maintain liaison with the appropriate congressional committees. The staff would not duplicate the basic functions of these organizations.

A permanent industry advisory committee should be organized to advise the National

Space Council and the Director of Civil Space (if appointed) on U.S. space enterprise and space industrial competitiveness. This committee should be organized as an element of the Vice President's Space Policy Advisory Board announced in April 1989. The committee would respond to requests from the National Space Council and the Director of Civil Space, review national strategies and actions, and offer counsel on its own initiative. It would assist in proposing national objectives and plans for supporting the growth of space enterprise. Members of the committee could help inform Congress about matters such as the relationship between Government investment in applications-oriented research and private-sector investment in new space enterprise. Members of the industry advisory committee should be drawn from the highest ranks of business, industry, and academia (and not be limited to aerospace executives).

A national program for U.S. space industrial competitiveness should be established. The program should be based on a long-range vision of the role the Nation should play in projected world space markets, related specific national goals for each sector of space enterprise, and strategies for achieving them. The U.S. Government's level of involvement and commitment should be clearly indicated, particularly for the research, early developmental, and startup phases of space ventures, when partnership between the Government and industry is especially critical. Development of these goals and strategies should be carried out jointly by the Government — at the level of the National Space Council and the Director of Civil Space — and the private sector, with participation by the industry advisory committee.

Agency-Level Support to New Space Enterprise

The U.S. Government should vigorously encourage and support space enterprise. Encouragement and substantive support should be provided to emerging space business sectors that are potential contributors to national space competitiveness or where private-sector investment is likely to result in more commercial investment and involvement in space. Such support is typically essential during the research, development, and startup phases of a space-related business involving new products or services, or space infrastructure.

To make such support available on a timely basis, NASA funds for commercial space development should be substantially increased to expand its commercial space outreach programs, to increase access to space, and to enhance the NASA Centers for the Commercial Development of Space. Regular access to space should be increased by using the Space Shuttle or advanced transportation systems (through Joint Endeavor Agreements), sounding rockets, expendable launch vehicles, Space Station *Freedom*, and related public- or private-sector infrastructure (on a purchase or lease basis) and equipment. Such access should be provided at no cost for precommercial-phase research where established criteria are met by competing applicants.

The NASA Centers for the Commercial Development of Space should be expanded and extended wherever centers are producing results of value to industry. Measures of effectiveness should be reviewed and enhanced, and objective critical reviews should be conducted as a basis for decisions for extending or discontinuing Government funds for specific

centers. Continued funding should be tied to industry orientation and productive output, including patented products and processes. Consideration should be given to establishing additional centers to explore, jointly with industry, potential new opportunities and the need for new technology to avoid or reduce recurring costs in areas such as telecommunications, data and sample-return and research support, and orbital-processing equipment for industry-oriented microgravity research and life sciences. Consideration should also be given to establishing a business-oriented center (or adapting an existing center) to encourage new space product market sectors by drawing on product concepts emerging from other centers.

Several other measures should be considered to help contain the risk of new space industries and thus simplify meeting capital requirements. Where commercial space ventures are in the early revenue stage, transportation assistance should be provided at reasonable cost through supportive pricing policies, Space Systems Development Agreements (which provide for deferred payments to be made from the revenue stream), and through the Centers for the Commercial Development of Space. New measures may need to include Government development of technology to lower the cost of transportation (such as may eventually result from the National Aerospace Plane program and other initiatives). The Office of Commercial Programs should have the funding and authority to lease or purchase commercially available infrastructure when needed to support access to space.

New ventures typically are faced with demonstrating that they can manage various types of risk: technical, schedule, cost, and market. Clearly, the roles Government agencies can play, including that of a good customer, help offset such risks and improve the industry's attractiveness to investors. These policies will ultimately return benefits to the American people in terms of taxable revenues, solutions to national concerns, higher living standards, international prestige, and world competitiveness.

The U.S. Government should develop or facilitate alternative financing approaches to help meet the capital needs of new space enterprises. Such approaches could be invoked if the commercial financing market fails to meet the capital needs of a new space enterprise important to the national interest. Raising capital in today's economy is a major obstacle to commercial development of space because of the history of delays, long payback periods, and perceived risk. Some assistance may be essential to achieving early successes in new sectors of the space market. The primary approach is for Government agencies to

Detail of *Spacelab I Payload Integration*, acrylic by Charles Schmidt

help offset private-sector risk and cost to increase attractiveness to investors.

Various alternative mechanisms could be employed. One example might be zero-coupon bonds, each targeted to a particular venture, convertible into common stock of the venture at the holder's option. All funds invested would be from the private sector, with a specified percentage required to be purchased by the venture as a long-term investment. Part of the principal (but not the interest) would be guaranteed by the U.S. Government, but the enterprise would still be at risk.

The U.S. Government should be prepared to serve as an initial anchor tenant and key customer of new private-sector space products, services, and infrastructure. This measure would apply where the proposed product, service, infrastructure, or facility is consistent with Government program needs, is commercially available or can be made available on a commercial basis without Government development, and is reasonably priced. This measure is particularly appropriate where subsequent benefits can be expected to accrue to the development of new space products or services, or where the market for the product, service, facility, or infrastructure is expected to be transferred to the private sector.

Typically, a space venture in its early phases finds its principal barrier to startup and growth to be the uncertain market for the new product, service, or facility being offered. The Government can use its purchasing power to promote space ventures whose offerings meet appropriate criteria, such as those listed in the previous paragraph. The Government customer should not influence configuration of a leased facility in a manner that might inhibit its later primary use by the private sector. Whenever possible, the

Detail of *41-C Training*, acrylic by George Guzzi

Government should procure services, not hardware, to reduce the amount of Government operations and achieve economies. Procurement regulations and procedures should be reviewed to facilitate the Government's role as a customer of commercially offered infrastructure, facilities, products, and services.

Congressional Support

Congressional committees have played an important role in promoting the development of space enterprise. In addition to supporting and encouraging the initiatives taken by industry, the executive branch, and Government agencies, Congress alone can act on two recommendations.

Congress should give the executive branch authority for multiyear commitments for the purchase or lease of commercially offered space goods or services. Such authority should be used when it is essential to the orderly development of space business that is initially dependent on Government customers. The

development time and cost involved in bringing space products, infrastructure, facilities, and services to market make evidence of such long-term commitments important to generating capital. Multiyear appropriations may be needed for long-term lease of commercial infrastructure. Where it is otherwise consistent with Government needs and the national interest, judicious use of such authority is warranted.

Congress should enact legislation that provides substantial incentive to industry to invest in space technology in support of U.S. space industrial competitiveness. Such measures might include permanent research and development tax credits for commercial applications-oriented space technology at a level above the 20 percent currently in effect for general industry or a reduction of capital-gains taxes for space enterprises.

Functional Recommendations

After the Committee made its initial review of issues and technology, it selected several functional areas for emphasis to clarify the strategies needed to encourage progress in the commercial space sector. Each functional area addresses issues of importance to U.S. space industrial competitiveness, cutting across all pertinent technologies and market sectors:

- Policy stability and consistency,
- International competition and cooperation,
- Finance and private-industry incentives, and
- Public and political opinion.

Below are the Committee's overviews of each functional area, followed by related recommendations. The key recommendations in the preceding section were formulated on the basis of the Committee's summary review of work in each of these functional areas.

Policy Stability and Consistency

Between the unveiling of President Reagan's commercial policy in 1982 and today, much attention has focused on what the Government should do to facilitate the development of the commercial space industry. Creating stability and consistency of policy at the highest level of the Government is the most critical consideration in planning for the future. To achieve this stability and consistency, the country must first have a comprehensive national goal to guide all Government space actions. Policy must be formulated at the White House level and closely coordinated with Congress and industry, both of which should contribute to the formulation of these goals. The policymaking process must clearly address long-range Government objectives and the requisite agency responsibilities for carrying them out. Most important, policy must be consistently and diligently implemented by all affected departments and agencies.

Executive Department Actions

Set general and sector-specific space industry objectives, time scales, and milestones with the help of space industry advisors. Clear objectives are easier to communicate and implement. The objectives should be quantitative and their attainment measurable in terms meaningful to business (for example, revenue growth, market share, and investment targets). Industry should have strong representation in this process.

Specific space industry sector-level goals proposed by the forthcoming report of the American Institute of Aeronautics and Astronautics, *Issues in Strategic Planning for Commercial Space Growth*, form a useful starting point. This report is based on a series of workshops on commercial space in which more than 90 space specialty experts participated.

Establish a disciplined and realistic policy-formulation process that is responsive to a long-range vision of space enterprise and includes the interests of the commercial space community. Policy derived through consensus and accommodation can win the full support of the Government and industry. Policy with that kind of backing would minimize future vacillation and avoid or reduce conflicts between different industry sectors. The formulation process should involve all parties who have a stake in policy promotion and success, including Congress, executive branch organizations and agencies, and the private sector.

Establish a formal policy-implementation and followup process with clear and detailed plans for existing and new policies. To promote more timely implementation and closer adherence to policy, a followup process is needed. This followup process will increase industry confidence and help stimulate commercial investment.

Within each agency involved, designate a senior official to be responsible for commercial space. This individual, preferably at the assistant secretary level or the equivalent, would be responsible to the Director of Civil Space on behalf of his or her agency for coordination of civil and commercial space matters. Focusing responsibility and accountability this way for the implementation of policy within each agency is the first step toward consistent application.

NASA Actions

Designate a senior official at each field center to be responsible for commercial space policy implementation. The field center network is NASA's real strength in terms of manpower, facilities, and equipment. To make these valuable resources available to the private sector and to promote better understanding of the space industry's role in advancing national space program objectives, top-level local support at each center is urgently needed.

International Competition and Cooperation

Space is not only a realm in which commercial markets will emerge; it is also a strategic field that will be key to economic interests in the next decade and beyond. As global competition in the space industry accelerates, America must leverage its strengths, assuming technological and market leadership in strategically selected space markets. The U.S. Government and industry will need to work together to develop a competitive and strategic advantage for the industrial use of space.

Within this framework, joint activity should be directed toward reducing the risk of space ventures in significant areas and removing barriers that impede industry progress. A global market perspective is needed, as are efforts to minimize barriers such as antitrust and foreign ownership restrictions. A proactive strategy is needed to penetrate foreign markets, along with a strategy to expand America's domestic market.

Presidential Actions

Emphasize international competitiveness in a revised presidential policy on space and its commercial use. The development of foreign commercial space capabilities is a key issue facing the future success of U.S. space businesses. At present, with the exception of satellite communications, foreign efforts are better focused and organized than their U.S. counterparts. America must recover its market share in several critical space markets by focusing on competitiveness.

Executive Department Actions

Ensure that intellectual property is adequately protected internationally. Extending U.S. patent laws to cover activities on board U.S. space vehicles is an important first step. Common international patent procedures and longer patent periods are measures for consideration. The U.S. Government should lead international efforts to bring order to the protection of intellectual property, including the licensing of technology.

Have the Departments of State and Commerce propose unified policy and procedures for technology-transfer controls for executive branch or legislative action. A technology-transfer policy that balances the following considerations is needed:

- Various routes of technology transfer such as export, international partnerships, teams, mergers, and equity; mobility of technical personnel; open literature, conferences, and the academic environment; and espionage;
- Reciprocity in technology exchange;
- Economic interests of the United States and its trading partners; and
- U.S. foreign policy interests.

Identify foreign nontariff trade barriers and negotiate with other countries for equal market access. Nontariff trade barriers sometimes take the form of arbitrary local standards designed to favor proprietary products and exclude imports. Such barriers should be made the subject of negotiations, including those in support of the General Agreement on Trade and Tariffs (GATT) to broaden market access.

Ensure that U.S. companies have top priority for receiving technology transferred from NASA and other agencies. One possible step would be to require reciprocity agreements with countries that want to obtain advanced technology other than through an export license.

Assist industry in assessing the level of foreign government intervention in developing competing commercial space technologies and markets. The Department of Commerce, with the assistance of NASA, should track the role and participation of foreign governments in the development and marketing of commercial space enterprises. The department should make this information available to U.S. entrepreneurs on request. The National Space Council, the Director of Civil Space, and the Vice President's Space Policy Advisory Board should consider these assessments in their deliberations on goals for U.S. industry. The U.S. Trade Representative's office will also be able to use this information in its negotiations with other nations.

Assist U.S. companies during their development and startup phases to overcome the high cost of early research and access to space by providing use of Government infrastructure and transportation. This assistance might include no- or low-cost transportation on the Space Shuttle, expendable launch vehicles, sounding rockets, aircraft, and

Space Station *Freedom*, as well as the use of special equipment and Government or leased infrastructure.

Apply strategic and economic considerations in choosing goals for space industrial competitiveness. Trade studies should be conducted to identify areas appropriate for international competition and those better suited for international cooperation. These studies should identify U.S. space initiatives that can leverage private-sector investment with limited impact on the U.S. budget.

Finance and Private-Industry Incentives

Many issues affect financing for private-sector space ventures, but most important of all is the absence of established commercial markets. Today, the U.S. Government remains the major customer for the space industry. Although commercial markets exist for some space ventures — notably satellite communications, launch services, and remote-sensing data — the overall space market is immature. This is the critical hurdle for the commercial financing of space ventures.

Executive Department Actions

Act as a bridge guarantor of debt financing until insurance becomes available and cap third-party liability for commercial space ventures. The limited capacity of the insurers makes launch insurance unobtainable until shortly before a launch. The absence of insurance has sometimes been a barrier to debt or equity financing. Without limits on third-party liability, insurance will be excessively expensive and largely unavailable.

Restructure Government procurement regulations. Authorization should be granted for the following:

- Timely procurement of commercially provided infrastructure services,
- Broader guidelines for acting on alternative and unsolicited proposals to develop commercial space infrastructure, and
- Adequate liability coverage for contract termination on the part of the U.S. Government.

As noted in the "Key Recommendations" section, multiyear authorizations and appropriations should be sought from Congress to help support commercial enterprise.

NASA Actions

Improve the existing commercial agreements program. NASA can increase the incentive to industry in three ways:

- Granting private-sector payloads higher priority and more timely manifesting,
- Increasing the availability of deferred payment agreements, and
- Further reducing processing time for Government space transportation agreements.

Continue developing joint endeavors with U.S. industry to find promising areas for investment in space that have the potential for contributing to the economy. The U.S. Government and industry should cooperate by identifying enabling technology that is driven by market demand. Industry can also capitalize on suitable technology already available, quickly adapt to changing market needs, and bring new products to market at a faster pace.

Establish multitiered pricing policies for space transportation based on payload nationality and, for U.S. payloads, maturity and other attributes of the project. The current pricing policy evolved from the

one-time launch of communications satellites. It is unreasonable to assume that all market sectors are mature enough to justify the same transportation costs. Price incentives should be based on the development stage of the project. Areas requiring early research should be eligible for reduced rates because the risks and market uncertainties are too high for industry to bear high transportation costs.

Encourage more industry participation in identifying research areas that are related to applications of space products and processes at the Centers for the Commercial Development of Space. By focusing on industry needs, the Centers for the Commercial Development of Space program can become a more effective tool for increasing U.S. technological competitiveness. Another way to encourage direct industry participation and to accelerate technology transfer is to introduce an industry principal investigator exchange program.

Use part of the Small Business Innovation Research program to stimulate space research directed toward space industry goals. To encourage innovation, this program provides incentive for entrepreneurs to take risks. The Government should embrace the Small Business Innovation Research program as a way to stimulate space research geared toward commercial goals or advances in enabling technologies, not just toward supplementing NASA or DOD research requirements. The program should also help in developing feasible business plans and in obtaining private financing. This policy would limit the current use of the program as "grant" money or supplemental R&D funding and accelerate the drive toward development of commercial space opportunities.

Political and Public Opinion

The President and Congress have agreed that private-sector involvement in space is important to the economic future of the Nation. NASA has a legislative mandate to support the commercial development of space to the fullest extent. NASA responsibilities in fulfilling this mandate include providing clear and accurate information about the economic value of space enterprise and programs supporting the development of U.S. enterprise in space.

Detail of *Aerospace Plane*, acrylic by Stan H. Stokes

NASA does a good job of informing the public, communicating the excitement and importance of space exploration. As NASA continues building on this foundation, the role of the private sector should be integrated into the portrayal of space. Public information programs about space enterprise should be coordinated among participating agencies and companies to obtain the greatest benefit.

NASA Actions

Increase materials, speakers, exhibits, press releases, and reports about

commercial space opportunities. Resources for responding to emerging public interest must be at hand. Within reasonable spending levels, NASA should continue to stimulate and promote private-sector interest in commercial space. The "What's in it for you" commercials developed by the U.S. Space Foundation are particularly effective.

Unify diverse outreach efforts by routinely emphasizing several key themes about the commercial development of space. These themes should address four points:

- Specific potential benefits to the individual,
- The importance of space enterprise to the United States as an international competitor,
- The economic advantages of the orderly transition of selected space functions to the private sector, and
- The Nation's policy commitment to commercial space.

Materials should be made available for further use by other agencies and the private sector.

Use terms other than "space commercialization." Use terms such as "space industrial competitiveness," "space enterprise," "commercial development of space," and "economic growth through space" in all releases and outreach efforts. These terms are more appropriate than "space commercialization" in describing the content and objectives of national policy and are less laden with negative connotations.

Better educate the media about industry in space. Developing a strong relationship with the media will assist in conveying fundamental messages about the commercial development of space. Facility tours and interviews with managers and researchers will help journalists present an accurate, well-informed picture to the public.

Link public outreach to the life of communities or regions through existing NASA affiliates. NASA Small Business Innovation Research contracts have spent or committed $175 million in contracts to 446 firms in 40 states. Other existing ties to communities include the nationwide network of NASA field centers, Industrial Applications Centers and affiliates, Computer Software Management and Information Centers, and applications teams, which reach across 32 states.

Use the strong local and regional ties of the universities and companies affiliated with the Centers for the Commercial Development of Space to increase awareness of the benefits of space commerce. One recurring theme in addressing public, political, and scientific opinion is the potential value of cooperation with the universities affiliated with the centers. These 48 universities have a direct interest in the success of the centers, and their affiliation signals institutional commitment to economic development through space industrial competitiveness. Universities have effective public information mechanisms and are often regional opinion leaders. The 183 companies affiliated with the Centers for the Commercial Development of Space can also provide effective outreach.

Enhance congressional liaison, focusing on the relationship among Government-sponsored R&D, commercial investment, and new business development. This theme should be documented and communicated as often as possible. Cooperation and communication should be considered with third-sector organizations such as the National Academy of Sciences,

the National Academy of Engineering, the Business-Higher Education Forum, and the Council on Competitiveness, which have expressed strong support for increased Government-funded R&D.

Reach out to science leaders and scientists in disciplines not traditionally involved in aerospace. This outreach should be oriented toward both the total industry-in-space program and linked to specific results of space-based research conducted by the private sector. It should also provide information on research opportunities, facilities, and funding in cooperation with the private sector.

Assist key industry leaders in communicating the economic importance of space industrial competitiveness. Business leaders are a constituency of likely support. NASA should explore innovative ways to reach and develop its relationship with them. Participating in nonaerospace trade shows and business conferences, establishing information links with local and state economic development interests, and leveraging the network of groups affiliated with NASA commercial development programs should help broaden the base of support from this important group.

Address U.S. business leaders in a range of industries. Use targeted publications, participation in nonaerospace trade shows and conferences, and links with local and state economic development interests. NASA should recognize that many knowledgeable business people are not convinced that they can get payloads into space today, and they have serious doubts about access in the future. Conferences and briefings should also be tailored to the financial community to expand knowledge and stimulate broader interest in space enterprise.

Endnotes

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[3] NASA Advisory Council Task Force on International Relations in Space, *International Space Policy for the 1990's and Beyond* (Washington, DC, October 1987), p. 24.

[4] *Ibid.*, pp. 5-6.

[5] NASA Office of Commercial Programs, *NASA Commercial Programs: A Progress Report 1988* (Washington, DC, July 1988).

[6] The Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC, September 1988).

Acronyms

ACTS Advanced Communications Technology Satellite, a NASA program

CPAC Commercial Programs Advisory Committee

CNES Centre National d'Etudes Spatiales, the French space agency

COMSAT Communications Satellite Corporation

DARPA Defense Advanced Research Programs Agency, a U.S. DOD agency

DOD U.S. Department of Defense

EOSAT Earth Observation Satellite Company, a joint venture of Hughes (now General Motors) and RCA (now General Electric Astro) formed to privatize LANDSAT, the U.S. remote-sensing system

ESA European Space Agency

GATT General Agreement on Trade and Tariffs

INTOSPACE European consortium

NASA National Aeronautics and Space Administration

NASDA Japan's National Space Development Agency

NIST National Institute of Standards and Technology (formerly National Bureau of Standards), an agency of the U.S. Department of Commerce

PAM Payload Assist Module, McDonnell Douglas's upper stage

R&D Research and development

SBIR Small Business Innovation Research, a Government program that funds development projects at small businesses

SDI Strategic Defense Initiative

SPOT System Probetoire d'Observation de la Terre, the French remote-sensing system operated by SPOT Image Company

TOS Transfer Orbit Stage, Orbital Science Corporation's upper stage

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CPAC Meeting Speakers
John Bliven
Center for Commercial Space

Charles Bugg, Ph.D.
Center for Macromolecular Crystallography
University of Alabama, Birmingham

H. Hollister Cantus
Lockheed Missiles
Space and Systems Group

Cort Durocher
American Institute of Aeronautics and Astronautics (AIAA)

James C. Fletcher, Ph.D.
NASA Administrator

Joel Greenberg
Princeton Synergetics

Jerry Grey, Ph.D.
AIAA

James Harford
AIAA

Frank Jelinek
Center for Advanced Materials
Battelle-Columbus Labs

Martin Kress, Ph.D.
Staff Assistant Counsel, Committee on Commerce, Science, and Transportation
U.S. Senate

Dale D. Myers
NASA Deputy Administrator

The Honorable William Nelson
U.S. House of Representatives

Kenneth Pedersen
NASA Office of External Relations

James T. Rose
NASA Office of Commercial Programs

J. Michael Smith
NASA Office of Commercial Programs

Courtney A. Stadd
R. Duffy Wall & Associates

Barbara A. Stone, Ph.D.
NASA Office of Commercial Programs

Secretary William Verity
U.S. Department of Commerce

The Honorable Robert Walker
U.S. House of Representatives

Peter W. Wood
Consultant

NASA
James T. Rose
Lawrence F. Herbolsheimer
J. Michael Smith
Barbara A. Stone, Ph.D.
Sylvia Fries, Ph.D.
John R. Yadvish
Bernard F. Hannan
Susan Y. Edgington
James E. Ball
Candace D. Livingston
Elaine B. Peterson
Craig Crutchfield
Bonnie S. Papadatos
Kevin C. Rock

Air Products and Chemicals, Inc.
Lanny R. Patten
Charles E. Anderson
James T. Christy

Boeing/Peat Marwick Commercial Space Group
Joseph Rutter
Francis A. DiBello
H. Scott Finer
Gregory Hager
Ahroon Henderson
Johnnie Huffman
John L. McIver
Robert O'Connor
Nancy Ruel
Timothy Ryf
Robert Schick
Bradley Schwartz
Jennifer Visick
Craig Voorhees
Denena Washington

Boeing Support Services
Carol Cella
Rick Turnbaugh

Business-Higher Education Forum
Don M. Blandin
Judith Irwin

Carter/Cosgrove & Company
Zane Carter
Therese Manning
Tammy Martin

Council on Competitiveness
Alan Magazine
Daniel F. Burton

Kernan-Schloss Associates
Adam Kernan-Schloss
Leslie Albin
Mary Shafer

Princeton Synergetics
Joel Greenberg
Carissa Christensen
Clay Durr

T.E.M. Associates
Doris Smith
Ann Manning
Kevin C. Rock

CPAC Video Coordinators
Philip E. Culbertson
External Tanks Corporation

Courtney A. Stadd
R. Duffy Wall & Associates

Charles D. Walker
McDonnell Douglas Systems

Peter W. Wood
Consultant

CPAC Video Participants
Anthony P. Arrott, Ph.D.
Payload Systems, Inc.

Kevin Barquinero
NASA Office of Space Station

James W. Barrett
Intec

Robert J. Bayuzick, Ph.D.
Center for the Space Processing of Engineering Materials
Vanderbilt University

Robert Berry
Ford Aerospace

John Bossler, Ph.D.
Center for Mapping
Ohio State University

Richard E. Brackeen
Martin Marietta Commercial Titan, Inc.

Charles Bugg, Ph.D.
Center for Macromolecular Crystallography
University of Alabama, Birmingham

Daniel F. Burton
Council on Competitiveness

John M. Cassanto
Instrumentation Technology Associates, Inc.

Roger Crouch, Ph.D.
NASA Microgravity Science and Applications Division

Philip E. Culbertson
External Tanks Corporation

Ray A. Cull, Ph.D.
Dow Corning Corporation

Francis A. DiBello
KPMG Peat Marwick Main & Co.

Steven D. Dorfman
Hughes Aircraft Company

Dennis Dunbar
General Dynamics Commercial Launch Services

June Edwards
NASA Office of General Counsel

John Egan
The Egan Group

Murray Felsher, Ph.D.
Washington Remote-Sensing Letter

Bruce W. Ferguson
Orbital Sciences Corporation

Steven H. Flajser
Fairchild Industries, Inc.

Stephan W. Fogleman
NASA Office of Space Science and Applications

Charles R. Gunn
NASA Office of Space Flight

Frederick B. Henderson III, Ph.D.
The Geosat Committee

Douglas A. Heydon
Arianespace, Inc.

Brian L. Hoekstra
Center for Commercial Crystal Growth in Space

Wesley Hymer, Ph.D.
Center for Cell Research
Pennsylvania State University

Richard K. Jacobson
Spacehab

F. Timothy Janis, Ph.D.
Aerospace Research Applications Center

Eugene F. Kadar
Conatec, Inc.

Gilbert W. Keyes
Boeing Commercial Space

Jack R. Knox, Ph.D.
Amoco Chemical Company

George A. Koopman
American Rocket Company

Carol S. Lane
Office of Commercial Space Transportation
U.S. Department of Transportation

David H. Langstaff
Space Industries, Inc.

Byron K. Lichtenberg
Payload Systems, Inc.

Charles A. Lundquist, Ph.D.
Consortium for Materials Development in Space
University of Alabama, Huntsville

Jeffrey Manber
Space Foundation

John L. McLucas, Ph.D.
QuesTech

Michael J. Meier
KRS Remote Sensing

Michael A. G. Michaud
U.S. Department of State

David Moore
Congressional Budget Office

Stanley A. Morain
Technology Applications Center
University of New Mexico

Jason O'Neill
DSI

David Padwa
University Corporation for Atmospheric Research

Joseph Pelton
Intelsat

Christopher J. Posiadly, Ph.D.
3M Corporation

Wilbur Pritchard
SSE Telecom

Louie C. Rayburn
McDonnell Douglas

Victor H. Reis
Science Applications International Corporation

Alden Richards
Johnson and Higgins

James T. Rose
NASA Office of Commercial Programs

Martin A. Rothblatt
Geostar Corporation

Charles Sheffield, Ph.D.
Earthsat Corporation

Christopher Shove, Ph.D.
Florida Department of Commerce

Jerome Simonoff
Citicorp/Citibank

J. Michael Smith
NASA Office of Commercial Programs

Courtney A. Stadd
R. Duffy Wall & Associates

Jeffrey L. Struthers
Center for Space and Advanced Technology

David Thompson
Orbital Sciences Corporation

Lillian Trippett
Counsel
Subcommittee on Science and Space Applications
U.S. House of Representatives

Charles D. Walker
McDonnell Douglas Astronautics

Randolph H. Ware
External Tanks Corporation

Harvey J. Willenberg, Ph.D.
Boeing Aerospace

C. P. Williams
EOSAT Company

Peter W. Wood
Consultant

About the Committee

In July 1988, the Commercial Programs Advisory Committee (CPAC) was formally created. Committee members were drawn from the ranks of U.S. corporate chief executive officers and their university counterparts to provide NASA with a diverse, high-level industry viewpoint on commercial space business. As a subcommittee of the NASA Advisory Council, CPAC was chartered to assist NASA by reviewing policies and programs and by recommending strategies to implement national space policy goals. The mission is to promote greater investment and participation by the U.S. private sector in America's civil space program.

Edward Donley, Chairman of the Executive Committee of Air Products and Chemicals, Inc., was named to serve as CPAC chairman. Mr. Donley had served as chairman of the Business-Higher Education Forum from 1986 to 1988 and has served as chairman of the U.S. Chamber of Commerce. The members are active participants in many other national leadership organizations, of which the Forum and the Council on Competitiveness are two examples.

END

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